

**RESOURCE ALLOCATION, INCENTIVES AND
ORGANIZATIONAL STRUCTURE FOR
COLLABORATIVE, CROSS-FUNCTIONAL NEW
PRODUCT DEVELOPMENT**

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SUMMARY

New product development (NPD) is critical to a firm's long term viability. The ability to formulate, and execute, a comprehensive NPD strategy rests on knowledge and capabilities that are dispersed throughout the organization. Critical managerial decisions regarding long term decisions are, by definition, "high level" decisions that look at the big picture, simply because the details required to make more precise calculations do not exist or are highly volatile. Instead, allocation decisions are made in the hope that the "right" product will eventually emerge from the NPD organization (those people that implement strategy).

This thesis addresses important operational aspects relating to fundamental components of any successfully executed NPD strategy: the processes, incentives and structure of decision rights that should be implemented *given the objectives and capabilities* of the firm.

In the first essay (Chapter 2), we outline when a firm might prefer to compensate members of a NPD project team either, as individuals (e.g. based on their functional contribution to overall value) or as a team (e.g. based on the overall profit generated). We find that neither team nor individual based compensation is preferred for all types of projects. Specifically, when there is higher uncertainty, the firm can benefit by employing team-based compensation. We discuss the implications of our findings towards the firm's ability to pursue different types of projects.

Next, in Chapter 3, we look at the strategic resource allocation processes that are employed by firms in order to decide whether NPD initiatives get funded or not. We find that there is not a "one size fits all" resource allocation process that *all* firms should employ. Furthermore, we extend this finding by further by providing

a rationale explaining why even a single firm could benefit by employing multiple processes *internal* to the firm.

In Chapter 4, we empirically explore how key managerial levers of the firm (i.e. incentives, tolerance for failure, and project management structure) affect an individual's propensity to invest in a project. Our analysis brings forth several underexplored and novel aspects. We examine how multiple managerial levers work in concert with one another (revealing interactions that, to our knowledge, have not been exposed). We also recognize an important aspect of most (if not all) NPD contexts: the probability of success is strongly tied to the level of resources that are invested.

CHAPTER I

INTRODUCTION

Few would argue the critical role that new product development (NPD) plays for a firm's long term viability. As such, it is important for academics, and practitioners alike, to understand the factors that enable, or prevent, a firm from implementing an effective NPD strategy. Said differently, understanding what contributes to the inability of a project to "gain traction" in one firm, while "taking off" in another firm, is important.

Scholars have generated quite some knowledge regarding how to choose the appropriate portfolio of projects given the risk preferences and strategic objectives of a firm (Markowitz 1952, Fox et al. 1984, Loch et al. 2001, Loch and Kavadias 2002, Girotra et al. 2007, Chao and Kavadias 2009). One aspect of the NPD setting which is fairly unique is the fact that in many instances the project the firm wishes to implement is largely unknown. In fact this the early phases of product development have become known as the "fuzzy front end" of product development reflecting the vast uncertainty that surrounds decisions early on in the process.

Despite the presence of vast uncertainty, critical strategic decisions relating to the firm's NPD strategy must be made. These strategic decisions are, more often than not, made at the higher levels of the hierarchy, whereas the more detailed knowledge regarding the functional and technical capabilities to achieve specific objectives resides at lower levels in the hierarchy. The challenge then becomes how can the firm structure its processes, distribute decision rights, and administer incentives for the various stakeholders in order to extract the most information and encourage the stakeholders to act in the best interest of the firm.

A common objective throughout the subsequent three chapters is to find out when a particular type of organization structure (processes, decision rights, and incentives—implicit and explicit) is most appropriate. Such an objective takes a Markowitzian view of such organization structure in the sense that Markowitz (1952) identified that there is no optimal portfolio for all individuals, portfolios should be tailored to the risk preferences of an individual.

The subsequent chapters make the argument that there is no single organization structure that can be universally applied. rather, each firm must adapt its NPD organization to its strategic objectives and the context it operates in. Furthermore, in many instances we make the argument that, more often than not, firms will sell themselves short by implementing a single process, incentive structure or allocation of decision rights, across all departments and for all activities *within* a firm. This thesis is aimed at contributing to our understanding of under what circumstances a firm should use the various processes and organizational levers at its disposal to get the most from the resources within its (loose) control. Figure 1 presents a graphic that shows how the subsequent chapters are related to one another. Chapter 2 explores the relationship between a single project manager and the project team, while Chapter 3 raises this analysis to the higher, more strategic, level between the senior management and the project manager, and finally Chapter 4 evaluates various levers of the senior management when they are administered to either a single (heavyweight) project manager with full control over project decisions or to multiple functional managers. The over-arching picture is that in order to execute NPD strategy we need to understand *how to manage* the relationships that exist between the multiple stakeholders in the NPD organization, who are dispersed throughout the organizational hierarchy, at different levels and with different information. Each chapter explores a different relationship in an attempt to put together a more complete and holistic view.

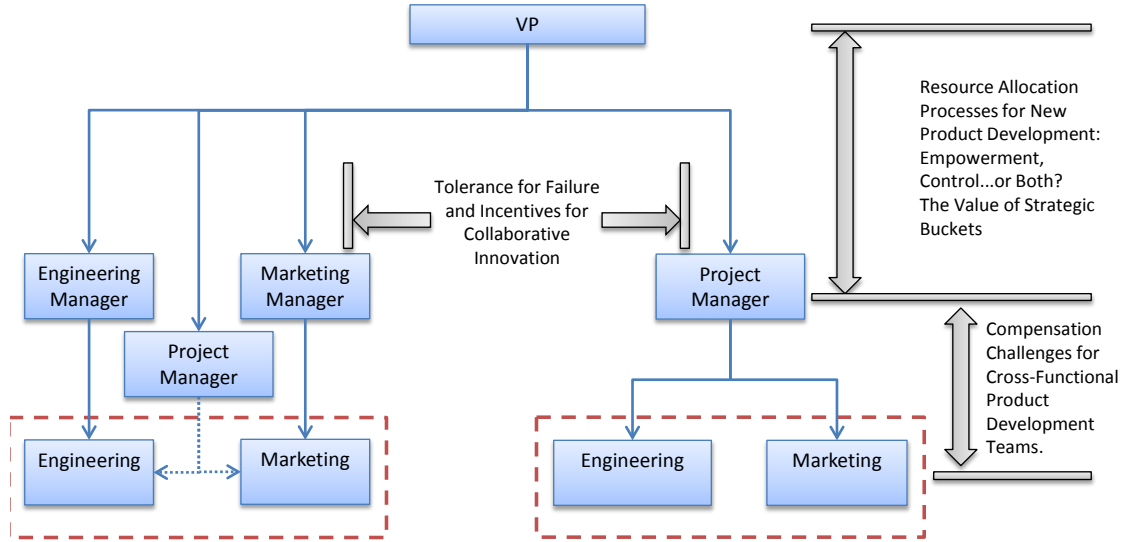


Figure 1: A typical NPD organization.

Chapter 2 begins with analysis concerning the project team level of the NPD organization. In this chapter we recognize the distinct organizational challenges of NPD projects regarding their execution. Specifically, these projects require specialized competencies, which prompt cross-functional collaboration. Collaboration implies significant interdependencies between the functions, including both, organizational factors (i.e. cross-functional coordination), and those arising from the problem structure, i.e. underlying relationships between the market and technology. Such collaboration takes place in an uncertain NPD setting, where the effort put forth by each functional specialist is non-verifiable. Within such a setting, senior management must ensure that functional specialists contribute towards management’s objective (to maximize profit). This study evaluates operational implications of incentives that compensate

specialists based on either, their functional contribution, or team output (project profit). Specifically, we look at how, project uncertainty, functional interdependencies, and team heterogeneity, affect management’s optimal choice of compensation. We uncover key sources of tension associated with management’s decisions regarding compensation: management benefits by employing team incentives for projects with high uncertainty; however, when there exists substantial diversity regarding the specialists’ capabilities (cost of effort), functional incentives are preferred. Interestingly, we show that management benefits by offering specialists that exhibit coordination synergies, compensation that is based on functional contributions.

In Chapter 3 we look at the strategic level of resource allocation processes within the firm. There are, two levels of resource allocation associated with the execution of portfolio management: the strategic level that decides high level programs to fund, and the more tactical and level associated with the detailed task allocation (more typically studied by operations scholars). In this chapter, we address the former, more strategic level of resource allocation. The decision regarding whether to fund a particular new product development (NPD) initiative has substantial implications for firm performance. However, at the time resource decisions are made, initiatives are rarely well defined; decisions rely on specialized knowledge residing at different levels within the organization. In response, firms employ processes that either emphasize control over budgeting (top-down), or exploit the detailed knowledge from lower ranks in the organizational hierarchy (bottom-up). We address the challenges associated with choosing the “right” resource allocation process (RAP), given two important factors: (i) the asymmetry of information between stakeholders (how refined is the knowledge of the initiative’s difficulty), and (ii) the organizational norms that affect managerial choices, i.e. a firm’s “tolerance for failure” towards managers of NPD initiatives. Our normative model accounts for the agency setting, and explicates the features associated with the “right” RAP: how decision rights are distributed between

stakeholders, and the form of compensation employed. No single RAP is dominant for all initiatives, even within a single organization. Bottom-up empowerment is beneficial for initiatives with greater expected difficulty, whereas top-down control is better for more standard initiatives. We also consider “hybrid” processes and find that a RAP based on an industry practice known as *strategic buckets* can offer the firm better results (higher profitability, and a larger set of opportunities) than either top-down or bottom-up processes. We offer a theoretical justification for the use of strategic buckets, and reveal an interesting side effect of organizational norms that penalize managers for failure: they enable the implementation of “hybrid” processes without the need for complex and impractical compensation schemes. Implications for project selection are discussed.

In the final chapter (Chapter 4) we theoretically develop and empirically test propositions evaluating key factors that affect a project manager’s propensity to invest resources in a NPD project. Most organizations employ collaborative innovation teams to manage innovation projects. While the use of collaborative innovation teams is a good starting point, an organization’s ability to innovate can be enhanced by managing risk-taking behavior through monetary incentive schemes and through an organizational culture that tolerates failure. This paper reports the results of a controlled laboratory experiment aimed at understanding how tolerance for failure and incentives impact the decisions of project managers engaged in a collaborative innovation initiative. We find that subjects invest at a higher level when the reward is high or when the penalty is low. We also find significant interaction effects between project control, reward, and penalty. When project control is shared, subjects do not internalize the effects of reward or penalty as much as they do when control is with one individual. The implication is that the positive influence of rewards (and the negative influence of penalties) is dampened when control is shared in a collaborative innovation team. Finally, we show when and how subjects alter their appetite for

risk depending on the rewards and penalties offered by the firm. When rewards and penalties are balanced so that both are high or both are low, subjects tend to exhibit greater risk appetite. Collectively, these results highlight how the firm can use rewards and penalties to influence resource allocation and risk appetite in collaborative innovation initiatives.

CHAPTER II

COMPENSATION CHALLENGES FOR CROSS-FUNCTIONAL PRODUCT DEVELOPMENT TEAMS

2.1 Introduction

Firms that engage in new product development (NPD) projects are critically dependent on the ability of cross-functional teams to work collectively towards the common project objective. However, assuming the *de facto* existence of such cross-functional congruence of objectives is simply not realistic. The specialized and uncertain nature of NPD tasks performed by distinct functions, primarily marketing and engineering, and the interactions that arise during the NPD process, present challenges regarding senior management's ability to establish such congruence.

Cross-functional interactions emerge during a NPD project through multiple sources: they may be an organizational outcome (i.e. different organizations are more, or less, effective at managing coordination and collaboration through specific rules or routines, see Mihm et al. 2003), or they may be environmental factors relating to the market and technology, which define the particular problem the NPD team is addressing (Erat and Kavadias 2008, Oraopoulos and Kavadias 2009). Their presence, however, poses an important managerial challenge: senior management needs to account for them when setting objectives, and respective performance plans, for NPD teams (Feltham and Xie 1994, Loch and Tapper 2002). Faced with such challenges, senior management resorts to “proper” incentive and compensation structures that try to align the objectives of the project stakeholders (i.e. senior management and the functional specialists) towards the common – and beneficial to the firm – profit

maximization, while accounting for the synergies, or coordination challenges, that exist between the functional experts (Griffin and Hauser 1996, Dutta et al. 1999, Balasubramanian and Bhardwaj 2004).

NPD tasks present additional challenges when it comes to rewarding contribution: tasks are characterized by significant uncertainty associated with their outcome, coupled with the inability to observe and measure the *precise* amount of intertwined stakeholder efforts. Thus, the criticality of properly setting the objectives and associated rewards becomes of paramount importance. Improper administration of the objectives and performance plans may result in unnecessary value loss due to intra-organizational friction or conflict.

Past literature has recorded the challenges of such cross-functional interactions, with a special emphasis on the classic friction between marketing and engineering (Allen 1985, Souder and Chakrabarti 1978, Griffin and Hauser 1996). Typical examples of the tension attributed to this dyad could be: marketing stating that their contribution is not valued by the firm, or by engineering, or engineering complaining about unequal compensation of the effort they exert towards the project objective. However, the majority of the extant literature has focused on recording the causes of friction, and measuring their effect on project performance. Instead, we aim to understand how senior management can employ a basic lever, such as the incentives implied by a compensation plan, to accommodate these realities, (e.g. lack of communication and coordination), while maximizing firm profits. Therefore, we focus on the different structures employed in performance plans in an effort to understand which ones offer the best results. Faced with this situation, the project manager chooses between two (typical) performance plans employed in practice (Sarin and Mahajan 1991): functional (input) or team (project output) rewards schemes. These two plans capture a key trade-off: the former offers a more precise signal of effort (i.e. there is less uncertainty associated with the observed measure), yet it induces a less congruent

objective; the latter offers a more congruent objective among stakeholders, yet this comes at the cost of a less precise signal of effort.

Our aim is to investigate how senior management’s preference towards either incentive plan depends on four specific characteristics unique to the NPD context: i. the *uncertainty* associated with the project; ii. the *correlation* between the factors affecting each function’s uncertainty; iii. the *coordination* exhibited by the NPD organization; and iv. the team *heterogeneity* regarding each functions capability (their cost to exert effort). In particular, we ask the following research question: When will senior management prefer to offer the specialists a performance plan based on their (observable) functional contribution, as opposed to one that uses the project outcome (profits) as the (observable) baseline?

In order to answer this question, we develop a normative model, where a senior manager determines the form of compensation plan (incentives) to offer a cross-functional NPD team of specialists, in order to maximize the senior manager’s utility (net profit) for a specific project. The NPD functions are characterized by their ability to coordinate on the project, while the project itself, is characterized by the uncertainty associated with the specific market and technology environment. Each stakeholder makes the following decisions: senior management decides the type, and magnitude, of incentive plan; and the specialists choose their respective effort level. At the same time they are subject to two important contextual challenges: the uncertainty regarding the outcome, and the inability to discern the exact causes of either bad or good outcomes.

Our findings offer several managerial insights regarding the choice between different performance plans. We uncover a key source of tension that exists for senior management when deciding on the type of incentive to offer. We show that for projects that have high uncertainty associated with them, senior management prefers team-based incentives. However, when the capabilities of the project team are diverse

with respect to each specialists respective cost of effort, senior management would prefer a functional incentive plan. Thus, we are left with two common traits of an NPD project team, where each one drives senior management in opposing directions. Finally, we formally show a paradox regarding team behavior: When a NPD organization is comprised of functional specialists that coordinate well with one another, a trait conducive to teamwork, senior management would prefer *not* to offer team-based compensation. Said differently, senior management prefers to decouple the incentives of a NPD project team that exhibits significant synergies.

The rest of the paper is organized as follows: We discuss the relevant literature in § 2.2. Then, we introduce our model setup in § 2.3 and we present the model analysis in § 2.4: in § 2.4.1 we look at the effects of functional interactions when functional capabilities are homogeneous, *both* those resulting from organizational coordination and those representing the market and technology environment; and lastly in § 2.4.2 we discuss the implications of intra-team heterogeneity regarding the functional capabilities of the specialists on the NPD project team. We offer discussion of the respective results throughout the analysis, and offer concluding remarks in § 2.5.

2.2 Related Literature

Collaborative product development, specifically the interface of marketing and engineering, has drawn a lot of attention in the literature (see Griffin and Hauser 1996 and references therein). The relevant literature to our problem, is comprised of two streams of literature that have evolved in parallel: personnel economics (Lazear and Rosen 1981, Lazear 1995), a field largely developed in the late 1970's and early 1980's as a subset of labor economics, and cross-functional communication and conflict in NPD (Allen 1977, Souder 1978, Griffin and Hauser 1996). Our model conceptualization borrows elements from the literature on performance measurement (Baker 1992, and Feltham and Xie 1994).

The field of personnel economics (Lazear 1995, Lazear and Oyer 2008) has advocated a firm’s value, in its ability to “provide a mechanism for people to work together and take advantage of complementarities in their skills and interests.” (Lazear and Oyer 2008, p. 40). Yet, this work has focused, primarily, on job design of known tasks (Holmstrom and Milgrom 1991), or activities that are more repetitive in nature and less related to the realm of NPD organizations. In our study we specifically capture distinct characteristics (i.e project uncertainty, organizational and market/technology interactions and intra-team heterogeneity) associated with the functions relating to NPD project tasks. The focus of personnel economics is further established through two empirical studies of team incentives and complementarities (Ichniowski et al 1997, Hamilton et al 2003). We differ from these works because we highlight the operational effectiveness (e.g. the set of projects a given NPD organization can profitably undertake) of two different incentive mechanisms, namely a compensation plan based on each specialist’s functional input, versus one based on the project team output.

There is substantial evidence concerning the level of cross-functional “(dis)harmony” that exists between the functions involved in an NPD project (Souder and Chakrabarti 1978, Gupta 1986). A number of studies assume that the presence of disharmony presumes losses to the firm, and as such they aim to reveal how conflicting objectives translate into losses for the firm. Such studies verify the existence, and even predominance of, states of “disharmony” between R&D (engineering) and marketing. Specifically, Souder defines severe cases of disharmony as: “lack of interaction”, “lack of appreciation”, and “lack of trust” (Souder 1981, p.68, Souder 1988, p.9). Griffin and Hauser (1996) show that there is widespread empirical evidence of disharmony. We adopt a different approach. We analyze the decisions of a profit-maximizing senior manager, to explore/question Souder’s (1981) remarks¹ that senior management

¹“Organizational climates and reward systems often contributed to the unappreciative attitudes.”, see Souder 1981, p 69.

contributes to the presence of disharmony, and we show that in some instances, traits of disharmony may in fact be induced by senior management as a result of their profit maximizing objective. Thus, our insights are similar in spirit to those of Balasubramanian and Bhardwaj (2004) who show instances of ex-ante, de-facto conflicting objectives benefitting the profitability of the firm.

Conflicting objectives (Souder 1981, Mihm et al. 2003, Mihm 2009) or the lack of proper channels of communication (Allen 1977, Moenart and Souder 1996), have been cited as the source of substantial value loss in NPD projects. Balasubramanian and Bhardwaj(2004) explicitly consider the conflicting objectives between manufacturing and marketing, respectively (i.e. manufacturing minimizes cost and marketing maximizes revenue). They contrast firm profits in a duopoly setting under two settings: a “coordinated” scenario, where the firm makes both quality and pricing decisions; and a decentralized setting where manufacturing chooses quality and marketing chooses price, such that each function bargains in order to reach a “compromise”. They show that firms can earn higher profits under the decentralized scenario (i.e. implying a conflict driven outcome) in the presence of competitive pressure. They further propose that future research should address *incentive* issues in other contexts, specifically product development. Our research fills this gap.

2.3 Model Setup

Consider a firm that undertakes a specific NPD project². The project objectives require the skills of cross-functional experts, namely, marketing and engineering specialists. These specialists need to collaborate in order to complete the project and ultimately generate value for the firm. In order to retain tractability while still teasing out the effects of cross-functional collaboration, we assume the team consists of two functional specialists, and a “senior manager”.

²We employ the terms NPD initiative or NPD project interchangeably.

2.3.1 Functional roles within the NPD team

Each specialist contributes to the total value of the initiative through individual effort put towards their respective functional activities (e.g. marketing conducts consumer research and market analysis, while engineering develops, tests, and integrates product technology). In order for each expert to achieve a specific contribution, s/he exerts effort, e_i $i \in \{t, m\}$. We assume that the actual effort the specialists put into the project activities is *non-verifiable* to represent an important NPD reality: product development involves complex and highly specialized tasks, where observing the actions of an expert does not allow a “non-expert” to discern the amount of effort the expert puts into the project. In other words, even if a project manager believes that a functional specialist is not working hard, his/her claim would not stand on its own in a court of law³.

Additionally, we assume that the correspondence between effort and the ex-post realization of the functional contribution, is not a one to one mapping, even for the specialists themselves. This reflects another key property of NPD activities: despite aspirations of technology attaining a certain level of performance, and engineering specialists exerting effort to achieve it, they may over or under-shoot their objective. We represent the correspondence between functional contribution and effort as $v_i = e_i + \varepsilon_i$, where ε_i , $i \in \{m, t\}$ are normally distributed with a mean of zero, standard deviations of σ_i ⁴, and a correlation ρ . In an NPD context, σ_i represents the uncertainty experienced at the functional level, for the specific project. A reasonable assumption would be that, functional activities undertaken in well-known domains, experience less uncertainty (i.e. they are more incremental), while those that are not

³Our argument closely follows standard structural assumptions in the incomplete contracts literature (Hart and Moore 1988).

⁴Based on the incomplete contracts literature, in our model, the fact that the specialist’s effort is not observable, is not as critical as the fact that the ex-post contributions can not be traced back to effort. In other words, the only verifiable observations are the functional value contributions, v_i ; which, are themselves random variables, $v_i \sim N(e_i, \sigma_i^2)$.

so well defined (i.e. are more radical) will have a higher degree of uncertainty. At the same time we recognize that cross-functional NPD tasks may lead to outcomes that are not only influenced by function-specific knowledge, but also by the relationship between market and technology “environmental factors” that lie outside of the direct control of the functional specialists. We capture such dependencies by the correlation between ε_m and ε_t , which eventually define the correlation between v_m and v_t .

The functional contribution of each specialist (v_m and v_t for marketing and engineering) represents the cumulative output of all function-specific activities. As an example, a bicycle company that develops a new racing bike (the project), may consider metric(s) of the functional value contribution for the engineering specialists that relate to the strength (torsional rigidity), or weight of a carbon fiber frame. Similarly, they may employ metrics for the marketing experts such as the number of new or confirmed customers, or the size of their distribution channels.

2.3.2 Revenue generation and firm cost

The functional contributions to the NPD project define the firm revenue. We acknowledge that NPD outcomes are not simply the “sum of the functional parts”, but they rely on a significant amount of interdependencies (Dutta et al. 1999) between the functions engaged in the initiative. Some of these interdependencies are driven by exogenous factors (captured by the correlation between the realized functional contributions), but others emerge from the organizational rules and routines associated with collaboration. Previous research has already made the case that organizational interactions between the functional specialists may either create significant synergies, or may be the source of substantial costs. The effects of such functional interactions have been shown to be both, a potential dimension of competitive advantage, and a key determinant of project success (Gupta 1985, Griffin and Hauser 1996). In line

with this literature, we model the NPD project revenue R , as a function of the contributions made by the functional specialists, as well as the organizational interactions between the two functions for the particular initiative: $R(v_m, v_t, b) = v_m + v_t + bv_mv_t$. Thus, $b \in \mathbb{R}$ reflects the extent of coordination exhibited by the NPD organization. The interactions between the functional specialists may be complementary ($b > 0$), however we also include cases where the functional experts do not “harmoniously” coordinate with one another ($b < 0$) (Souder 1981). The NPD literature has repeatedly recorded the fact that coordination requires significant costs, such as the intensive and frequent communication, or unnecessary redesign efforts resulting from oscillatory nature of engineering change orders between NPD sub-groups (Mihm et al. 2003, Loch and Terwiesch 2008). In summary, our model allows for both positive (e.g. synergies) and negative (e.g. costly coordination or excessive meetings) value effects: in certain cases, the total value generated is greater than the sum of the individual functional contributions; on the flip-side, even if a function is able to “do all the right things” (e.g. marketing can gain substantial distribution and conduct effective marketing), the inability to effectively communicate the consumer needs to engineering, leading to inadequate design, harms the firm’s ability to appropriate returns from the project.

The resulting functional contributions have resource implications for the firm. The firm’s cost is a result of the NPD team’s respective contributions. We represent it by a quadratic function of the individual contributions, $c_f(v_m, v_t, b) = v_m^2 + v_t^2$. This representation of the firm’s cost echoes that of prior marketing models, where a higher “quality” contribution tends to be more costly (Moorthy 1984). Thus, the potential gross profit of the initiative is $\Pi(v_m, v_t, b) = R(v_m, v_t, b) - c_f(v_m, v_t)$. The quadratic nature of the cost captures the limiting effects of effort on value creation, i.e. no function can create infinite value through their effort.

2.3.3 The need for incentives

As we have indicated in § 2.3.1, the functional specialists exert personal effort in order to realize their respective functional contributions. This effort comes at a private cost $c_i(e_i) = c_i e_i^2 / 2$, $i \in \{m, t\}$. We follow related literature on collaborative innovation (Balasubramanian and Bhardwaj 2004, Bhaskaran and Krishnan 2009) and use a quadratic functional form to capture this cost of effort. Such cost is *private*, as it only impacts each expert's utility; however, the magnitude of the impact to the expert's utility is observed by all stakeholders (both experts and the firm)⁵. The parameter c_i represents each expert's respective capability, such that an expert with a high capability has a lower cost of effort, for the same expected contribution, as opposed to an expert with low capability. As a result of functional contributions (v_m and v_t) being stochastically determined, effort being non-verifiable, and each specialist incurring a private cost of effort, it becomes imperative that the firm employ some form of incentive compensation to ensure the proper effort commitment (Holmstrom 1979). Under such a compensation plan, each specialist must at least expect to earn their reservation utility (e.g. their outside employment option) \underline{U} ⁶.

2.3.4 Incentives and the choice of performance plan

The design of the performance plan for a NPD team is a central decision for the senior management of a firm. Senior management has the discretion to choose between different methods of rewarding the functional specialists. Thus, the main decision is how to best allocate remunerations for the NPD team members in the context of a specific initiative (σ_i, ρ) , the capabilities of the NPD organization (c_i) , and the organizational ability to coordinate (b) . We restrict our attention to two performance

⁵We remind the reader that although the parameter c_i is known the effort can not be verified, and thus the problem remains one of moral hazard.

⁶In our presentation, we normalize the reservation utility to zero. In an associated technical report we show that our results carry over to the general case of non-zero reservation utilities. It is readily available from the authors.

plans that are documented as typical forms⁷ of compensation schemes in matrix, project-based or strictly functional-based organizations (Allen 2000): i) *Functional incentives* (F) - The firm bases each specialist's performance plan solely on their own functional contribution; or ii) *Team incentives* (P) - The firm bases their performance plan on the combined outcome of the initiative (profits).

If the firm chooses to implement a performance plan based on functional incentives, each specialist receives compensation: $w_{fi} + k_{fi}v_i$ where w_{fi} represents the fixed wage (salary) portion of the plan, and k_{fi} linearly parameterizes the bonus based on the realized contribution. This yields utility for each specialist: $U_{fi} = w_{fi} + k_{fi}v_i - c_i(e_i)$. However, if the firm chooses to compensate the specialists using team incentives, each one receives the same bonus: $w_{pi} + k_p\Pi$, where Π represents the gross profits, w_{pi} is the fixed wage offered to each specialist i and k_p linearly parameterizes the common bonus plan. This yields utility for each specialist equal to $U_{pi} = w_{pi} + k_p\Pi - c_i(e_i)$.

Definition 1. STAKEHOLDER UTILITY

1. Under team incentives (P):

(a) Each manager $i \in \{m, t\}$ has expected utility:

$$\mathbb{E}_{\varepsilon_m, \varepsilon_t}(U_{pi}) = u_{pi} = k_p(e_m + e_t + be_me_t + b\rho\sigma_m\sigma_t - (e_m^2 + e_t^2 + \sigma_m^2 + \sigma_t^2)) - (c_i e_i^2) / 2$$

(b) Senior management's expected utility is:

$$\mathbb{E}_{\varepsilon_m, \varepsilon_t}(U_{ps}) = u_{ps} = (1 - 2k_p)(e_m + e_t + be_me_t + b\rho\sigma_m\sigma_t - (e_m^2 + e_t^2 + \sigma_m^2 + \sigma_t^2))$$

2. Under functional incentives (F):

(a) Each manager $i \in \{m, t\}$ has expected utility:

⁷Formally, we restrict ourselves to two different types of linear contract. The assumption of linear contracts is common in the literature, as it is a stylized representation of bonuses commonly used in practice.

$$\mathbb{E}_{\varepsilon_m, \varepsilon_t}(U_{fi}) = u_{fi} = k_f e_i - (c_i e_i^2) / 2$$

(b) *Senior management's expected utility is:*

$$\mathbb{E}_{\varepsilon_m, \varepsilon_t}(U_{fs}) = u_{fs} = (1 - k_{fm})e_m + (1 - k_{ft})e_t + b e_m e_t + b \rho \sigma_m \sigma_t - (e_m^2 + e_t^2 + \sigma_m^2 \sigma_t^2)$$

Then, the objective of the firm and the relevant constraints are as follows:

Definition 2. *The senior management's objective is:*

$$\max_{P, F} \left\{ \begin{array}{cc} \begin{array}{c} \underline{P} \\ \max_{w_p, k_p} u_{ps} \\ \text{s.t.} \\ u_{pi} \geq 0 \\ e_i = \arg \max_{e_i} u_{pi} \\ i \in \{m, t\} \end{array} & , \quad \begin{array}{c} \underline{F} \\ \max_{w_f, k_{fi}} u_{fs} \\ \text{s.t.} \\ u_{fi} \geq 0 \\ e_i = \arg \max_{e_i} u_{fi} \\ i \in \{m, t\} \end{array} \end{array} \right\} \quad (1)$$

Figure 6 shows a timeline that explicitly outlines the sequence of events and decisions in our model.

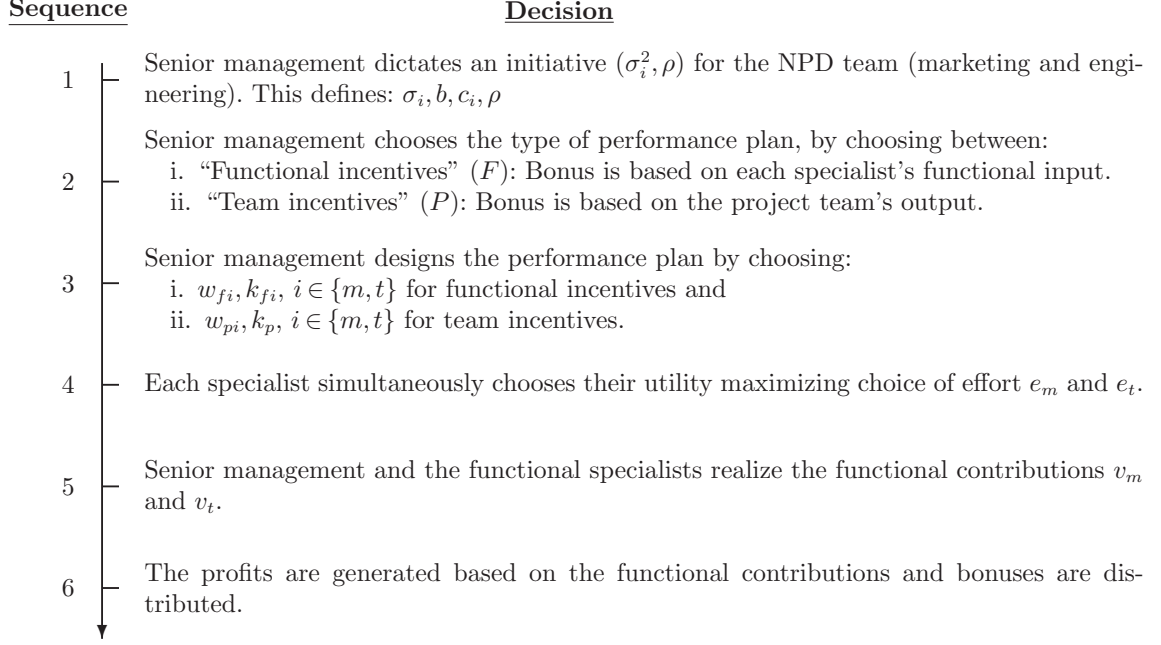


Figure 2: The sequence of decisions and events.

2.4 Model Analysis

In this section we present our analysis on senior management’s choice of performance plan given a particular NPD initiative (σ_i^2, ρ) . In addition to outlining the optimal choice of performance plan we delineate the set of initiatives that the firm can profitably pursue. In doing so, we provide a comprehensive assessment of which performance plan is applicable for various NPD organizations (e.g. those with NPD organizations that enjoy benefits of synergistic coordination, or those that incur substantial cost in order to coordinate); and the potential initiatives the company faces (e.g. NPD projects that extend existing product lines through slight changes, as opposed to more radical efforts that aim to introduce completely new products).

2.4.1 Homogeneous capabilities

We consider the fully symmetric case, $c_t = c_m = c$ and $\sigma_t = \sigma_m = \sigma$ (in § ?? we relax the assumption of symmetric costs). The expected profit of the firm under team and

functional incentives, and the expected utility of the functional specialists under each respective incentive plan becomes:

$$u_{ps} = (1 - 2k_p)(e_m + e_t + be_me_t + b\rho\sigma^2 - (e_m^2 + e_t^2 + 2\sigma^2))$$

$$u_{pi} = k_p(e_m + e_t + be_me_t + b\rho\sigma^2 - (e_m^2 + e_t^2 + 2\sigma^2)) - (ce_i^2)/2$$

$$u_{fs} = (1 - k_{fm})e_m + (1 - k_{ft})e_t + be_me_t + b\rho\sigma^2 - (e_m^2 + e_t^2 + 2\sigma^2)$$

$$u_{fi} = k_fe_i - (c_ie_i^2)/2$$

We use the sub-game perfect, Nash equilibrium concept to evaluate the effort choices of the stakeholders of the NPD initiative. Backward induction dictates that we first analyze the strategic interaction between the functional specialists, in order to determine their utility maximizing decisions given a performance plan; then we solve for the contract parameters k_p and k_f that yield the firm's (non-negative) profit maximizing solution, finally, we solve for the profit maximizing choice of performance plan P or F .

2.4.1.1 The actions of the functional specialists.

Under a performance plan that promotes team incentives, both specialists receive a bonus based on the total profit of the initiative, Π_p . Consequently, the functional specialists *directly* depend on one another in order to maximize their respective utility. By contrast, under a functional incentive plan, each of the specialists is compensated solely based on their own contribution, (i.e. v_m or v_t), and they need not be concerned with the actions of the *other* agent; such actions do not *directly* affect their own compensation. Similarly, under functional incentives, each specialist is not explicitly concerned with the cost of the firm because, once again, as shown in Definition 1 the firm cost does not appear in their utility. However, note that these are only *direct* implications for the specialists. The actions of the *other* specialist and the firm's cost have an *indirect* effect on the specialists: senior management accounts for the actions of *both* specialists, *and* the firm cost, when choosing a particular compensation

structure. We make this more precise in Lemma 2.

In the following lemma we present the symmetric best response functions under each type of performance plan. We then discuss how these determine the equilibrium actions. (All proofs can be found in the Appendix).

Lemma 1. THE EQUILIBRIUM EFFORT OF THE SPECIALISTS.

- Under a functional incentive plan each (symmetric) specialist exerts the same equilibrium effort ($e_{fm}^* = e_{ft}^* = e_f^*$), $e_{fi}^*(k_{fi}, c) = \frac{k_f}{c}$
- Under a team incentive plan each specialist's best response action is: $e_{pi}(e_{pj}, k_p, b) = \frac{k_p(1+be_j)}{c+2k_p}$, which results in equilibrium effort levels: $e_p^*(k_p, b, c) = \frac{k_p}{c-k_p(b-2)}$

Lemma 1 describes how the different parameters of the project impact the actions of the specialists for each respective performance plan. As expected, when the specialists operate under a functional incentive plan they do not consider the action (effort) of the other specialist, and thus their effort level is solely based on their personal capability (c) and the incentives offered (k_{fi}). Additionally, their choice does not depend directly on the organizational interdependencies (b); such organizational factors only influence their choice through senior management's choice of k_f .

However, under a team-based incentive plan, the specialists *do* consider both the organizational interdependencies *and* the actions of the *other* specialist. Only in the absence of any interdependency (i.e. $b = 0$), do we observe that the specialists are not concerned with each other's actions, similar to the choices under functional incentives. However, despite the fact that $b = 0$, each specialist's action under a team-based incentive plan is different when compared to the action they would take under a functional incentive plan. This is a result of the specialist's objective under team incentives being more congruent with the objective of the firm than the specialist's objective under functional incentives.

Note that even under team incentives, the specialists do not directly consider the amount of uncertainty associated with the initiative; their effort choices are independent of the variance (σ^2) associated with the initiative. This stems from our assumption that all stakeholders are risk neutral. However, the project uncertainty does factor into the specialists' equilibrium indirectly: project uncertainty enters their equilibrium actions through senior management's choice of optimal incentives. Lemma 2 describes the optimal incentives for each performance plan.

Lemma 2. THE FIRM'S INCENTIVE DECISION.

Define the following quantities: $\beta \triangleq b - 2$, $\gamma \triangleq 1 + 2\beta\sigma^2$, and $\xi = \frac{1}{2}(2 - b\rho)\sigma^2$.

- The optimal **functional** incentive plan is such that:

$$- k_{fm}^* = k_{ft}^* = k_f^* = \frac{c}{b+2(1-c)}$$

- The optimal **team** incentive plan is such that:

$$- \text{There exists } \bar{\sigma} \in \mathbb{R} \text{ such that when } \sigma \geq \bar{\sigma} \text{ then } k_p^* = \frac{c((3+8\xi\beta)-\sqrt{9+16\xi\beta})}{4\beta(1+2\beta\xi)};$$

when $\sigma < \bar{\sigma}$,

$$\text{then } k_p^* \text{ solves } G(k_p, \cdot) = \beta^2\gamma k_p^3 - 3\beta c\gamma k_p^2 + 2c^2(1+\beta+\gamma)k_p - c^2(1+2c\xi) = 0$$

- $w_f^* = w_p^* = 0$

Lemmas 1 and 2 confirm that when the specialists are symmetric with respect to their capabilities and uncertainties, both their efforts (e .) and the bonus compensation (k .) offered by the firm will also be symmetric. Given this observation we drop the subscript i throughout (except where necessary for clarity). Lemma 2 shows that the project uncertainty (σ^2) affects the specialist's committed effort indirectly when team incentives are employed. That is, it does so through senior management's choice of incentives, and more specifically, through the magnitude of the bonus compensation. However, the senior management only takes the project uncertainty into account in team-based incentive plans. This results from the fact that the stakeholders are all

assumed to be risk neutral, and therefore any uncertainty implications arise from non-linearities in the project profit; functional incentive plans do not account for the latter.

2.4.1.2 The choice between incentive plans.

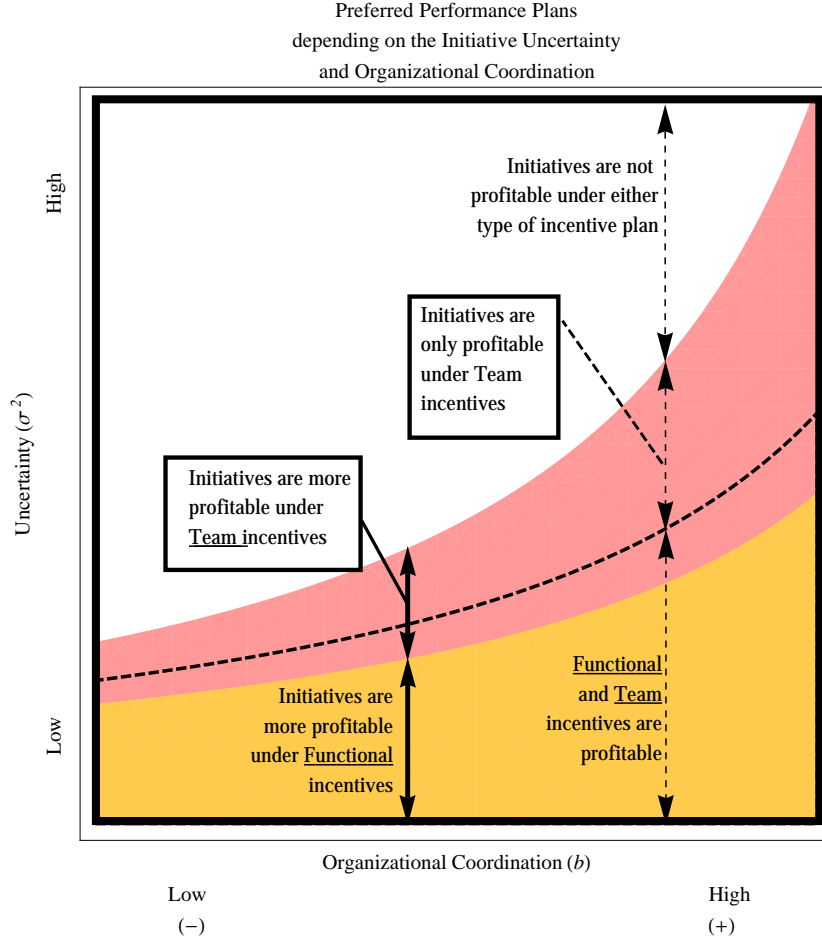
Proposition 1 outlines senior management's preferred incentive plan in the face of project uncertainty.

Proposition 1. THE FIRM'S CHOICE OF PERFORMANCE PLANS.

There exists an uncertainty threshold $\bar{\sigma} \in \mathbb{R}$ such that, for initiatives with low (market/technology) uncertainty ($\sigma < \bar{\sigma}$), the firm implements functional incentives, whereas for initiatives exhibiting high uncertainty ($\sigma > \bar{\sigma}$), the firm implements team incentives.

There are two major factors that hinder the firm's ability to achieve maximum profit: the strategic interaction between the specialists, and the project uncertainty. The first only plays a role when team incentives are employed, as discussed in Lemma 1. However, project uncertainty affects profitability under both incentive plans, and this is where we realize the advantage of team incentives. As a result of the congruence between the specialists' and senior management's objectives under team incentives, all stakeholders share in any benefit or loss associated with the project uncertainty. However, under a functional incentive plan, senior management bears the full benefit or loss associated with the project uncertainty. Thus, when the project uncertainty is low, senior management marginally benefits from the functional specialists sharing the uncertainty, but senior management bears the losses associated with a lower effort due to the specialists' strategic interaction. Yet, under a team incentive plan, as project uncertainty increases, the benefits from sharing the exposure to uncertainty, outweigh the losses from strategic interaction and a team incentive plan becomes the preferred

Figure 3: The firm implements functional incentives for the lightly shaded region and team incentives for the darker shaded region (dimensioned by the bold arrows). Functional incentives allow the firm to profitably pursue projects falling within the region outlined by the dashed line, while team incentives allow the firm to pursue projects in both shaded regions.



choice. The following Corollary describes the managerial insights from implementing the optimal performance plans.

Corollary 1. THE SET OF FEASIBLE INITIATIVES

The set of NPD initiatives the firm can implement under functional incentives is strictly smaller than that under team incentives.

Another important insight relates to the set of feasible initiatives. The set of feasible initiatives represents all the projects that senior management could pursue,

and still expect to earn non-negative utility, under a particular type of incentive plan. Figure 3 presents a graphical representation of these sets in a $\sigma^2 - b$ plane. As shown in Proposition 1, there exists a maximal level of uncertainty beyond which an initiative is deemed unprofitable, irrespective of the incentive structure employed. We find that the firm can always accommodate more uncertainty with team incentives than with functional ones. The intuition behind this result is similar to that of Proposition 1. The benefits of congruent objectives allows stakeholders to share the project uncertainty, which serves to moderate effort more effectively in the presence of high uncertainty.

2.4.1.3 The effect of functional interdependencies on the choice of incentive plan.

Proposition 2 lays the foundation for understanding how the relationship between the environmental factors, i.e. the uncertainty faced by the marketing specialist and that faced by the engineering specialist (i.e. ρ), affect senior management's choice of performance plan.

Proposition 2. EFFECT OF INTERDEPENDENCIES ON COMPENSATION AND PROFIT.

- *Under functional incentives, the optimal compensation plan k_f^* is unaffected by the correlation ρ .*
- *Under team incentives, the optimal compensation plan k_p^* is decreasing (increasing) in the correlation ρ when $b > 0$ ($b < 0$).*
- *Under functional incentives, senior management's optimal expected utility u_{fs}^* is increasing (decreasing) in the correlation ρ when $b > 0$ ($b < 0$).*
- *Under team incentives, senior management's optimal expected utility u_{ps}^* is increasing (decreasing) in the correlation ρ when $b > 0$ ($b < 0$).*

When senior management employs a functional incentive plan, the effort choices made by the specialists do not take the organizational interactions into consideration. However, as outlined in Lemma 2, senior management does consider both types of interdependencies: organizational interactions (b), and the correlation between the environmental factors (ρ). As such, senior management aims to induce behavior that is sensitive to the impact from these interdependencies. Thus, Proposition 2 shows that under functional incentives, senior management does adjust the bonus offered to the specialists according to the level of organizational coordination, but does not adjust the bonus according to interdependencies between environmental factors. This is a result of how the correlation figures into the firm profits under functional incentives: the benefits and losses associated with the external environment do not interact with the actions of the specialists (i.e. neither k_f nor e_i is present in the term $b\rho\sigma_m\sigma_t$ in Definition 1) and thus, given the risk neutral behavior of senior management this term does not factor into their decision.

However, the effects on team incentives are different. Although the directional effect of b is the same as under functional incentives, the way in which it figures into each specialist's effort choice is distinctly different: First, under team incentives, Lemma 1 showed that the specialists consider the organizational coordination when choosing effort; Second, senior management and the specialists share the benefits and losses associated with the direct effect of organizational factors (i.e. the term be_me_t), and the interaction between the level of organizational coordination and the correlation between external environmental factors, (i.e. the term $b\rho\sigma_m\sigma_t$). The fact that the stakeholders share the benefits and losses that stem from organizational coordination and the relationships between uncertain environmental aspects, drives the resulting relationship between correlation and optimal bonus. When senior management accounts for the correlation, it is critical to note whether organizational coordination exhibits positive or negative effects, since the correlation serves to magnify the value

created or lost through such coordination activities. The following corollary outlines how the interdependencies impact the projects that senior management is profitably able to pursue with the marketing and engineering specialists within their NPD organization.

Corollary 2. THE EFFECT OF INTERDEPENDENCIES ON THE SET OF FEASIBLE INITIATIVES

- *The set of NPD initiatives the firm can implement is increasing in b .*
- *The set of NPD initiatives the firm can implement is increasing (decreasing) in ρ when $b > 0$ ($b < 0$).*

Corollary 1 shows how team incentives allow the firm to pursue a broader set of projects than it could if it only implemented functional incentives. Now, Corollary 2 adds to this by noting the effects of interdependencies on the feasible set. Corollary 2 follows directly from the directional results of Proposition 2, whereby when profitability is increasing so too is the feasible set. We capture the effects of the organizational coordination on senior management's choice of performance plan in the following Proposition.

Proposition 3. THE CHOICE OF COMPENSATION PLAN AND INTERDEPENDENCIES.

For a given initiative (σ^2, ρ) , there exists a lower, and an upper, threshold level of organizational coordination $\underline{b}, \bar{b} \in \mathbb{R}$, such that:

- *When $b > \bar{b}$, the firm employs functional incentives.*
- *When $b \in [\underline{b}, \bar{b}]$, the firm employs team incentives.*
- *When $b < \underline{b}$, the firm is unable to profitably pursue the project.*

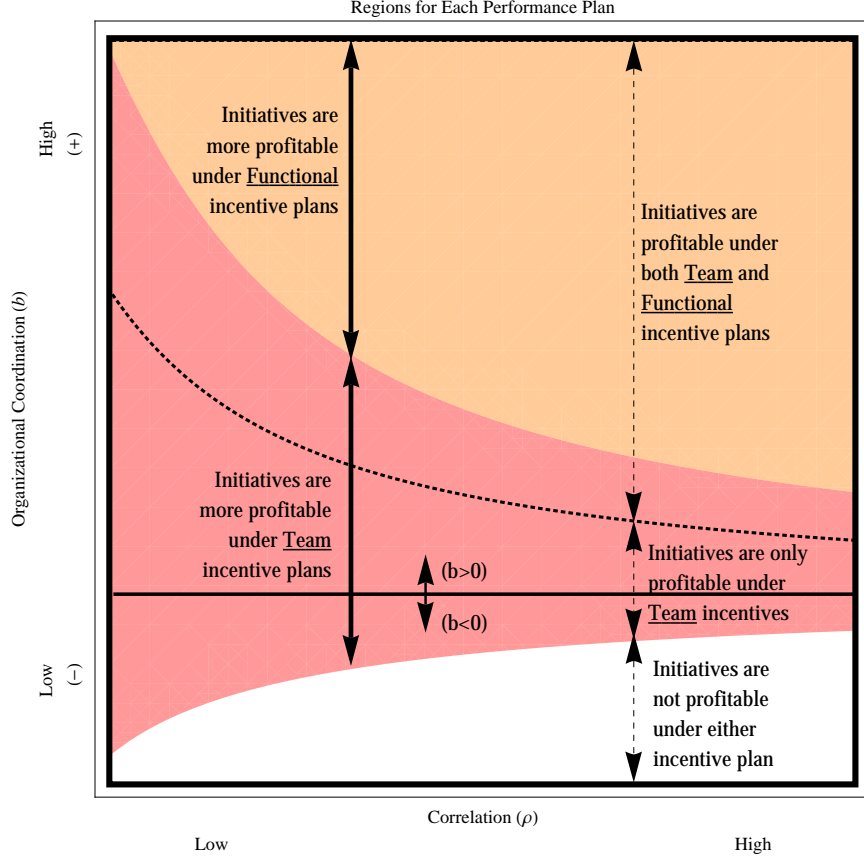


Figure 4: The firm implements functional incentives for the lightly shaded region and project incentives for the darker shaded region (as dimensioned by the bold arrows). Functional incentives can only profitably implement projects that lie in the region above the dotted line, while team incentives are only profitable for those projects that lie between the lower and upper dashed lines (as dimensioned by the dashed arrows).

Proposition 3 extends the intuition of Proposition 2 and is graphically presented in Figure 4. When we consider both dimensions of interdependencies, b and ρ , we show that for both incentive plans, increased organizational coordination has benefits regarding profitability. However, as coordination increases, senior management's preference towards functional incentives increases as well. To see this we can look at the case when the correlation is zero (i.e. the left-most portion of Figure 4); even in the absence of any correlation (i.e. the term $b\rho\sigma^2$ in Definition 1 plays no role), there exist direct effects of organizational coordination (i.e. the term be_me_t in Definition 1).

When the coordination exhibits synergies ($b > 0$), under team incentives the direct benefits are diluted through the strategic interaction and the shared profit between stakeholders. As such, under functional incentives we find that senior management enjoys a greater increase in relative utility than under team incentives. This suggests that senior management would prefer to employ functional incentives when the coordination is positive. However, the reverse is true when the coordination between functions is costly. In such situations, the fact that the impact is diluted through the strategic interaction, and shared by all stakeholders, benefits senior management. In summary, when senior management observes behavior, on the part of the specialists, that is conducive to teamwork (i.e. functions that coordinate well to create synergies), management would prefer to employ functional incentives that act to decouple the efforts of each specialist.

Once we allow for interdependencies between functional uncertainties ($\rho > 0$), we see that the effects of coordination are magnified. In other words, as the uncertainty associated with the underlying market and technology become more closely interrelated ($\uparrow \rho$), any organizational synergies exhibited by the functional specialists are further magnified such that senior management's preference for functional incentives is stronger. Likewise, for costly coordination, as the linkage between market and technology uncertainty becomes stronger, senior management's preference for team incentives becomes stronger as depicted in Figure 4.

2.4.2 The effect of NPD team diversity

Thus far we have considered functional specialists with symmetric capabilities (i.e. the same private cost of effort). Our assumption has enabled us to illustrate key trade-offs that arise when choosing the form of compensation, even in the case of symmetric functional specialists. Yet, in reality NPD teams will likely exhibit some asymmetry with regards to their functional capability. It may be the case that the

technology already exists, yet hasn't been introduced to a particular market (which would imply a lower cost of effort for engineering and a higher cost of effort for marketing) or vice versa. In this section we consider functional specialists with heterogeneous capabilities, and examine the implications of this team-diversity factor on senior management's choice of performance plan. Note that, as our example suggests, we do not associate the term "capability" with a *good* or a *bad* specialist. Instead, we conceptualize the capability as being a property of the strategic initiative itself: a low (high) capability specialist is the same as saying that the specialist faces a high (low) cost to search the solution space that characterizes the product development problem. In order to retain tractability, we revert to the case where the actions of the specialists do not exhibit any correlation. We represent a high capability (low cost) specialist's personal cost of effort by $\bar{c}(1 - \delta)$, and likewise, the low capability (high cost) specialist has a personal cost of: $\bar{c}(1 + \delta)$. Thus, \bar{c} denotes the mean capability of the NPD team and δ denotes the dispersion of capabilities. Proposition 4 discusses the profitability of the firm under the different incentive plans. It compares a cross functional team that has symmetric functional specialists, both with capability \bar{c} , to a team with diverse capabilities, $\bar{c}(1 - \delta)$ and $\bar{c}(1 + \delta)$.

Proposition 4. PROFITABILITY AND DIVERSE CAPABILITIES.

For a given NPD initiative (σ^2, ρ)

- *Under a functional incentive plan, the expected profit of the firm increases in the diversity of the project team capabilities (δ) .*
- *Under a team incentive plan, there exists a threshold $\hat{c} \in \mathbb{R}$ such that for $\bar{c} \leq \hat{c}$ the expected profit of the firm is non-increasing in the team diversity (δ) , and for $\bar{c} > \hat{c}$ the expected profit of the firm increases in δ .*

Under functional incentives the firm has the ability to tailor incentives to each

function's capability, while still ensuring that the specialists will exert enough effort. In other words, the intuition built in Lemma 2 still holds: specialists are only concerned with their own contribution and resulting compensation; as such, senior management offers a positive bonus for all feasible initiatives⁸ and the specialists always exert positive effort (i.e. they are never driven to their participation constraint). In the absence of any strategic interaction, the firm can always improve its profits when the specialists differ in their capabilities. Why is this the case? Because senior management can take advantage of the higher capability specialist. A higher capability implies a lower cost of effort, the benefits of one additional unit of effort from the low cost specialist are greater than the equivalent losses incurred by the high cost specialist, yielding an additional gain for senior management. It then results that the high capability specialist always exerts more effort as induced by senior management. Team incentives are different. Under team incentives the participation constraint of the specialists may bind. In the case of diverse capabilities, if the participation constraint is binding, it is always the low capability specialist who has a binding participation constraint. Under a binding participation constraint, the bonus offered to both specialists (k_p^*), is determined by the utility of the specialist(s) whose participation constraint is binding. The resulting k_p^* that senior management offers is linear in the capability of the specialist(s) with a binding participation constraint. From Lemma 1 shows, if k_p^* is linear in capability, then the equilibrium effort is independent of capability. As expected, the same holds true for the average capability, i.e. the effort exerted by each specialist is independent of the average capability. Still, the effort exerted, depends on the dispersion of capabilities. This results from the fact that k_p^* changes according to the efforts of both specialists, and with diverse capabilities the high capability specialist always exerts a higher level of effort (as s/he earns

⁸Recall, feasible initiatives are those projects that the firm expects to earn non-negative net profits.

a utility surplus by doing so). Thus, when the effort is high, the utility that senior management gains from the additional effort put forth by the higher capability specialist is less than the loss of utility surplus given to the higher capability specialist. As such, with high average capability, any increase in the dispersion of capabilities will cause a decrease in senior management's utility. For the opposite case, senior management gains more by exploiting the high capability specialist. Thus, senior management earns greater surplus when the dispersion increases.

The following Lemma, provides normative reasoning for empirical findings relating to the harmony that exists between the functional specialists on the NPD project team.

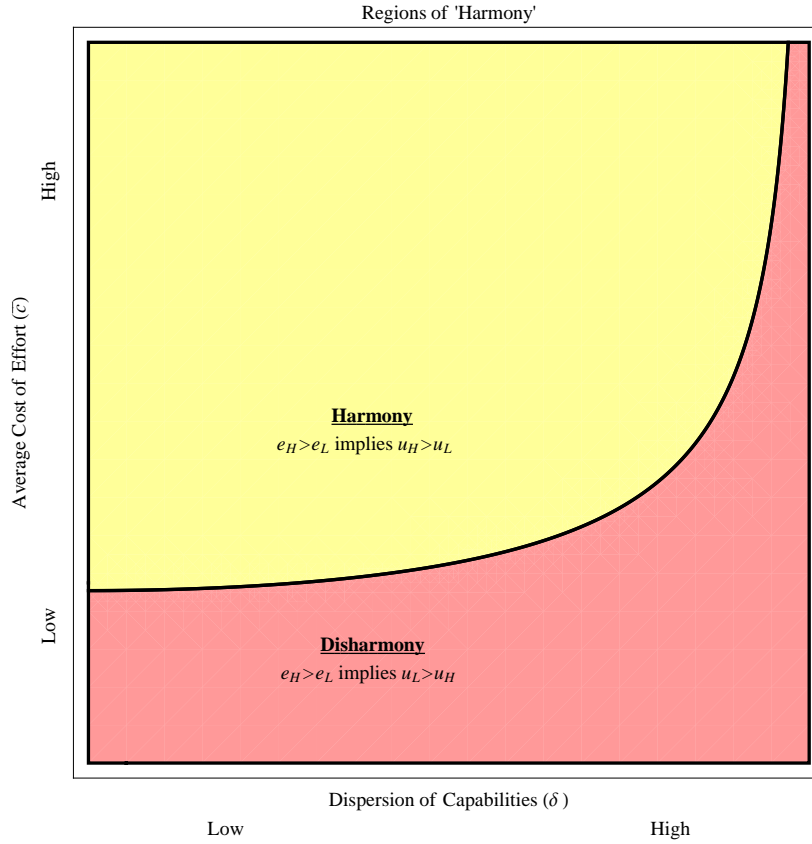
Lemma 3. COMPENSATION AND CAPABILITY DISPERSION.

When the firm employs functional incentives for a diverse NPD team:

- *A specialist with higher capability, exerts more effort than the lower capability one.*
- *A specialist with higher capability expects to receive a higher utility than the lower capability one, when $\frac{\bar{c}(1-\delta)}{8(1+\bar{c}(1-\delta))^2} > \frac{\bar{c}(1+\delta)}{8(1+\bar{c}(1+\delta))^2}$*

Lemma 3 sheds light on the previous empirical findings relating to the friction between marketing and engineering experts within a NPD project team (Souder 1981 and 1988, Griffin and Hauser 1996). As discussed in § 3.2, such studies have found the existence, and even predominance of, states of “harmony” or “disharmony” between R&D (engineering) and marketing. We define states of “harmony” as those when $e_{fi}^* > e_{fj}^*$ implies $u_{fi}^* > u_{fj}^*$, i.e. whoever exerts more effort is rewarded more. Lemma 3 makes the case that, such empirical observations, may be the result of optimal, profit maximizing decisions on the part of senior management. Lemma 3 is graphically depicted in Figure 2.4.2, showing regions of harmony, where the higher compensation is garnered by the specialist exerting more effort; and those of disharmony, where

Figure 5: In order to achieve profit maximizing results, the firm may optimally provide incentives that induce disharmony among the specialists. The respective effort and utility of the high (low) capability specialist is denoted by e_H (e_L) and u_H (u_L), respectively.



the higher compensation goes to the specialist who exerts less effort. As stated in Lemma 3 and shown in Figure 2.4.2, there is a greater degree of disharmony when the average capability of the specialists is low and when the dispersion of capabilities (diversity) is high.

Proposition 5. THE IMPACT OF PROJECT TEAMS WITH DIVERSE CAPABILITIES.

- *When the NPD team is comprised of specialists with diverse capability levels, the relative advantage of functional incentives increases.*
- *In the extreme case, as $\delta \rightarrow 1$, functional incentives become dominant over the*

entire range of profitable initiatives.

Proposition 5 captures an interesting source of tension faced by senior management: in an NPD context many project teams face significant levels of uncertainty. Our findings outlined in Propositions 1 and 3 would advocate team incentive structures in such situations. However, NPD projects rarely are staffed with functional specialists with identical capabilities; then, our results in Proposition 5 would suggest that senior management move towards employing functional incentive plans. This apparent tension bolsters the argument that firms need to be especially cognizant of both, the type of problems the NPD team faces (e.g. more radical or incremental projects), but also the characteristics of their organization: their ability to coordinate with one another, and their relative capabilities to accomplish their respective tasks.

2.5 Discussion and Conclusions

In this study we develop a model to address under what conditions a firm would prefer to offer a cross-functional team of marketing and engineering experts either an incentive plan that rewards functional inputs, or one that rewards the project team output. We recognize that such senior management decisions need to account for a set of important factors: i) the organizational complementarities or coordination losses, i.e. the ability of marketing and engineering to create synergies or the friction between them resulting in added costs; and ii) the interdependencies of the underlying market and technology factors the team faces, i.e. how interrelated are the marketing and engineering value contributions. The key trade-off that senior management faces is that, while functional incentives offer a clearer signal of each functional specialist's effort, the effort of each specialist is decoupled, thus they do not account for the impact to the total project outcome. Alternatively, team-based incentive plans encourage the functional specialists to think more holistically, such that they are more congruent with senior management's objectives (i.e. the maximum value for the specific NPD

project). Yet, they offer a noisier signal regarding the effort exerted by the specialists, since they base compensation on the profit, which encompasses the total uncertainty associated with the project value, and they induce the functional specialists to act strategically (i.e. to “game” one another).

We model this trade off in a principal multi-agent setting, where senior management faces moral hazard regarding the cross-functional effort exerted towards the execution of a NPD project. We analyze the problem in two distinct steps: first, we look at the optimal compensation plan for a NPD project when the functional specialists exhibit similar capabilities to identify the effects of the aforementioned tensions; then we examine the effect of diversity regarding each function’s private cost of effort (each function’s capability).

Three major insights emerge from our analysis regarding the preferred compensation plan; the first two concern homogeneous project teams, while the last relates to a project team that has heterogeneous functional capabilities. First, we show that for higher uncertainty projects, i.e. a high degree of uncertainty associated with the realized functional contributions, senior management prefers to offer each specialist a team incentive plan. Such an incentive plan is able to capitalize on both establishing more congruent objectives among the stakeholders (senior management and the functional specialists), and sharing the uncertainty associated with the initiative between senior management and the functional specialists. Thus, team based incentives moderate the effort expenditures based on the amount of uncertainty. Additionally, a team-based incentive plan enables the firm to pursue a broader range of projects than a functional incentive plan would. Said differently, only when employing team-based incentives, can the firm pursue initiatives with higher uncertainty.

Second, we find an interesting relationship between senior management’s optimal decision regarding compensation and the characteristics of the NPD project team. When senior management is considering a team comprised of functional specialists

who exhibit coordination synergies, a characteristic often associated with well functioning teams, management prefers to offer the specialists compensation that rewards their functional contribution. Said differently, team incentives benefit senior management when a team does not exhibit positive synergies, yet if they do exhibit such synergies, senior management would prefer not to reward the specialists as a team. The intuition behind this result is the fact that under functional incentives, senior management reaps the full benefit (or burden) associated with the value created (or lost) due to coordination. However, under team incentives, this value is shared among all stakeholders, *and* its effect is diluted through the strategic interaction that takes place between the functional specialists. In the end the benefit of coordination makes preferences for functional incentives stronger. Interestingly, functional interdependencies associated with the market and technology uncertainty (i.e. the correlation ρ), magnify the effect of positive or negative organizational coordination. Thus, senior management will aim to decouple the incentives offered to a team of highly coordinated marketing and engineering specialists, who work on a project where the market and technology are closely linked.

Third, we find that when a NPD team is characterized by diverse capabilities (cost of effort) to add value through their functional contributions, senior management prefers to offer a functional incentive plan. In other words, the ability to tailor incentives to functional capability allows senior management to extract greater benefit from the more effective specialist, i.e. the specialist with a lower private cost of effort. Interestingly, such a tailored functional incentive plan uncovers a second order effect that may provide an alternative explanation for the widespread findings of previous literature (Souder 1981) regarding the dis-harmony recorded in the marketing-engineering dyad (Griffin and Hauser 1996): we show that the firm may optimally induce pay-for-performance inequity between the functional specialists. In other words, we establish that depending on the average NPD team capability and

the diversity level, it can optimally happen that the firm offers lower compensation to the specialist that contributes more effort; an outcome that under many settings would create feelings of “unfairness”. Our finding not only lends insight to the observed tensions between the functions, but it also serves as a cautionary signal for interpreting self-reported measures of “internal performance” e.g. team member satisfaction (Sarin and Mahajan 1991) with the actual performance of the project for the firm.

Finally, when we compile our findings, we observe that senior management faces an interesting tension, often NPD project teams face both, projects with high uncertainty and project teams will have diverse capabilities. Senior management can benefit by employing team incentives when facing highly uncertain projects, yet the more diverse the team capabilities are the more senior management could benefit from offering functional incentives. This tension highlights the importance of senior management’s ability to understand, the type of projects their NPD teams face, the individual functional capabilities, and the NPD organization’s ability to coordinate between the distinct functions.

CHAPTER III

RESOURCE ALLOCATION PROCESSES FOR NEW PRODUCT DEVELOPMENT: EMPOWERMENT, CONTROL...OR BOTH? THE VALUE OF STRATEGIC BUCKETS

3.1 Introduction

The decision of whether or not to fund a particular strategic initiative can have substantial implications for the firm's viability (Wheelwright and Clark 1992, Cooper et al. 2001, Chao and Kavadias 2009). At the time such a decision is made, the initiative may not be fully defined, or precisely understood. Knowledge regarding what it takes to execute a specific initiative is dispersed across different levels of the firm's hierarchy creating significant asymmetries of information. As a result, the decision process (i.e which decisions are made by whom) that senior management implements, influences both whether the initiative is funded, and if it is, what the funding level will be. The fact that resource allocation processes (RAP) shape what initiatives a firm funds is not, by itself, new (Bower 1970, Burgelman 1983, Bower and Gilbert 2005). Yet, understanding *how* the chosen processes determine *which* initiatives the firm funds, is an important operational element that determines strategy execution.

The resource allocation processes employed in practice fall within two broad categories. In a *top-down* process, senior management dictates fixed levels of resources for middle management (i.e. project managers) to oversee, whereas in *bottom-up* processes project managers are granted *decision rights* (Aghion and Tirole 1997) to

determine the right level of resources (Maritan 2001, Chao and Kavadias 2010, Kavadias and Kovach 2010). As such, top-down processes aim to establish the efficient use of resources by maintaining *control*. In contrast, bottom-up processes aim to leverage the effective use of resources, by *empowering* managers to tailor resource allocation based on their expert knowledge of the challenges associated with the execution of the initiative. Since both types of processes are encountered in practice, a natural question arises: when is it best to employ a top-down process as opposed to a bottom-up one? These observations fuel a more general question regarding the existence of processes that combine the best elements of both approaches. Could such an “optimal” process be operationalized?

Scholars have long studied the efficient implementation of top-down resource allocation (Harris et al. 1982). More recently the Operations Management literature has explored decision making processes that account for the hierarchical nature of decision making within organizations (Siemens 2008, Chao et al. 2009, Loch and Sting 2010, Mihm 2010, Mihm et al. 2010). These studies have primarily emerged within the new product development (NPD) domain due to the obvious fit; NPD is highly specialized (Zingales and Rajan, 2001), with activities that require decentralized expertise, and it is central to the growth and livelihood of the firm. As such it requires substantial resources. However, most of these studies have focused on the private effort undertaken by NPD specialists and have not accounted for the existence of bottom-up resource decisions, i.e. budgets that are shaped by middle management.

In this study we seek to understand the drivers of profitable resource allocation. We account for both the hierarchical nature of the organization, and the asymmetries that exist between stakeholders, i.e. the middle management (PM) and senior management (e.g. a Vice President who acts as a proxy for the executive level of decision making within the firm). We capture the hierarchical nature of decision making through the use of a principal-agent model, where the PM (agent) must oversee the

detailed execution of the initiative (whether or not he¹ decides the *level* of resources he still must allocate them optimally), and the VP (principal) dictates the initiative based on strategic fit. We distinguish between the resource allocation processes based on which stakeholder (the PM or VP) chooses the level of resources (budget) to allocate to the initiative. Our model captures an important asymmetry between the VP and the PM, regarding their respective knowledge of the difficulty associated with the execution of the initiative. We allow the PM to fully understand the difficulty of the initiative (as expressed by the relationship between resources allocated and the likelihood that the initiative will succeed); in contrast, the VP only knows that the initiative may be one with *difficult task execution* or one with *simpler task execution*. In order to capture tensions between stakeholders that are driven by the organization itself, we choose not to focus on the personal (private) effort of the project manager (PM) as the source of any misalignment between the objectives of the VP and the PM. Instead, we posit that any disutility for the PM results from the risk of failing, and the ex-post penalties that he might incur. Thus, we consider the straightforward setting where the PM would rather be rewarded than penalized, and he chooses actions according to the utility he receives from each occurrence (success or failure). This interpretation of the organizational context makes the firm’s organizational culture an important element of our model (Kreps 1990, Hermalin 2008, Schein 2010). The culture determines the organizational norms which dictate the consequences a PM can expect following a failed outcome (i.e. the organizational penalty²).

Our findings show that, contingent on the information asymmetry between the stakeholders and the difficulty of the initiative, a top-down process may prove more

¹We adopt the convention that the agent is referred to as “he” while we refer to the Vice President (VP) as “she”.

²Such penalties may be as subtle as the manager receiving all the “unwanted” projects, or as explicit as being fired. They reflect the organization’s set of rules and routines, that define “how things get done,” and they represent a key dimension of the organizational culture: the “tolerance for failure” (Manso 2010)

beneficial than a bottom-up one, and vice versa. Thus, we offer normative support regarding the need for *both* bottom up and top-down processes to co-exist within organizations, as advocated early on by Burgelman’s (1983) seminal work³. We analytically characterize when each respective process is more beneficial: initiatives with high expected difficulty, benefit from a bottom-up process; however, when the expected difficulty is low, a top-down process is better. We then show that there does exist a resource allocation process that employs budgets and incentives tailored to the execution difficulty of the initiative, which outperforms both, i.e. the top-down and bottom-up approaches. Yet, the implementation of such a process for all types of initiatives is potentially involved (if not prohibitive) for most organizations to implement⁴. Fortunately, there is a silver-lining: solely implementing budgets tailored to the difficulty of the initiative, an industry practice known as *strategic buckets*, can still offer benefits over both the top-down and bottom-up processes. In other words, strategic buckets enable the firm to expand the set of initiatives it can profitably fund. Our findings add an operational perspective to two important discussions: first, we offer insights on how the decision structure defined by the respective RAP impacts which initiatives a firm funds (Bower and Gilbert 2005); second, we offer an alternative explanation for the use of strategic buckets in organizations as a means of effective resource allocation (Chao and Kavadias 2008).

The rest of the paper is structured as follows. We review the relevant literature in §3.2 and introduce our model setup in §3.3. Following our model setup we provide the analysis of our model in §3.4. In our model analysis, we first characterize the first-best solution in §3.4.1, then follow this with a characterization of the top-down and

³Burgelman (1983) advocates that project definition occurs both in a top-down and bottom-up manner, whereas we specifically study the process by which the resource level (i.e. budget) is decided upon. Then in a similar fashion, we note that bottom-up and top-down processes for resource level decisions need to coexist within a single organization.

⁴Mihm 2010 offers a rich discussion regarding why such tailored non-linear incentive contracts are hard to implement.

bottom-up resource allocation processes in §3.4.2 and 3.4.3, respectively. Then, we provide an exposition of a resource allocation process that captures elements of both the bottom-up and top-down processes in §3.4.4. Lastly, we close with a discussion and conclusions in §3.5.

3.2 Related Literature

A substantial body of research across various management disciplines, has addressed various challenges surrounding resource allocation decisions. Of these studies, the literature that is most relevant to our work comes from research in Operations Management (OM), Strategic Management and Corporate Finance.

Several scholars have looked at the resource allocation problem in an effort to answer the following question: should a firm fund (or continue funding) a specific initiative (e.g. Roberts and Weitzman, 1981, Teisberg 1993,1994, Huchzermeier and Loch 2001, Santiago and Vakili 2005)? This stream of research builds upon a long tradition in the field of Operations Research and considers a decision process where the decision maker and the executor of the project tasks are one and the same. We relate to the overarching objective of these papers, as we look at the decision process associated with resource allocation and the choice to fund a project. However, we take a different perspective as we account for the realities of the NPD process: hierarchical decision making, and the distributed nature of knowledge which gives rise to agency and incentive challenges. Recently, scholars in NPD have begun to account for the hierarchical nature of decision making (Siemens 2008, Terwiesch and Xu 2008, Chao et al. 2009, Mihm et al. 2010, Mihm 2010, Erat and Krishnan 2010). Two of these studies, lie closer to our work: Chao et al. (2009) and Siemens (2008). Specifically, Chao et al. (2009), being the closest, study a hierarchical setting where a senior manager (principal) chooses between “empowering” a business unit manager (agent) to adapt his innovation budget to the division sales, or to “control” the agent through

issuing him a fixed innovation budget . Given the funding policy, the agent decides to optimally allocate resources to exploration (long term) or exploitation (short term) initiatives. Chao et al. (2009) compare different funding policies, but they do not characterize the optimal funding decisions for the principal in each of these settings. We extend their setting to characterize and compare the optimal funding decision across different resource allocation processes. Although Chao et al. (2009) assume that the exact resource allocation is not observable by the principal, we posit that resource budgets are in fact observable by senior management and that there is a more suitable source of asymmetry between the stakeholders that arises from knowledge specialization as opposed to accounting “noise”. Siemsen (2008) explores another aspect of the hierarchical nature of the firm: the effect of career concerns on the task difficulty choice of the employee (agent). Siemsen focuses solely on the effects of career concerns, independent of any other incentive mechanism⁵, and given that the agent’s utility is reputation related. We build on his observation that specialists have more refined knowledge of the difficulty associated with project tasks, and we incorporate this insight to solve for senior management’s (the principal’s) optimal choice regarding the resource allocation process and actual resource allocation in order to maximizes firm profits.

Our research question also echoes prior attempts to determine the optimal resource allocation from the field of “capital budgeting” (Harris et al. 1982, Antle and Eppen 1985, Baiman and Rajan 1995), which has flourished in the Accounting and Corporate Finance disciplines. We share a common conceptualization of the resource allocation problem. We agree with the assumptions made in this stream of literature: decisions are decentralized and hierarchical; there exists asymmetry of information between the stakeholders; and that the compensation and incentive schemes rely on incomplete

⁵In a related follow up Katok and Siemsen (2009) elaborate on the principal’s use of the value of the promotion in order to influence the agent’s choice.

contracts. However, the context of NPD initiatives presents distinct challenges that are not of primary concern to this stream of literature: (i) the assumed returns on investment exhibit strong non-linearities (Loch and Kavadias 2002), different from the additive or linear profit functions predominantly used in capital budgeting; (ii) these non-linearities stem from strong complementarities between the resources allocated and the difficulty of tasks being executed, i.e. a disproportionate increase in the resources allocated is required for more difficult projects; (iii) the specialization know-how held by the project team is not imitable by the senior management of the firm and therefore substitution of effort across stakeholders may not be possible; finally (iv) the disutility of the agent may be a result of organizational norms (i.e. penalties resulting from a failed initiative) and not solely a result of effort put towards a project. Our model formulation specifically accounts for these distinctions and operationalizes the resource allocation process in an NPD setting.

Finally, we owe special credit to the seminal work of Bower (1970) and Burgelman (1983) in the Strategic Management discipline, as they offer substantial field evidence about the structure of the resource allocation processes found in organizations. Their insights have given way to a debate about the benefits arising from bottom-up versus top-down resource allocation processes, and they have informed many of the constructs of our model (for a thorough review see Bower and Gilbert 2005). However, the primary research method applied in these studies has been descriptive field research (Bower and Doz 1979, Burgelman 1983, Maritan 2001). We borrow their grounded theory to develop a normative model that seeks to explain their findings. In that vein, our work operationalizes the choice of resource allocation processes within a hierarchical organization and lends support to the observations that NPD processes require a hierarchical planning perspective (Anderson and Joglekar 2005).

3.3 Model Setup

In this section, we introduce the formal structure of our model. Consider a typical organizational hierarchy: senior management (the VP, i.e. principal) oversees a project manager (i.e. agent), who is responsible for the detailed execution of NPD initiatives. The project manager represents all of the interests and task specific knowledge of the entire project team; the VP acts as a proxy for the firm’s interests, and she is responsible for the implementation of a dimension of corporate strategy, through an innovative initiative. The VP, assigns the initiative based on a simple rule: does she expect the initiative to add value⁶ to the firm, i.e. is $\mathbb{E}[\Pi] \geq \hat{\Pi}$? Where $\hat{\Pi}$ is the minimum value the firm must gain from an initiative in order for it to be considered worthwhile. Prior research (Bower 1970, Burgelman 1983, Coen and Maritan 2010) has identified a critical factor that influences the decision to fund an initiative or not: the *structural context* in which the initiative is carried out (i.e. the “organizational design, and compensation plans that top executives can manipulate to influence indirectly what type of strategic initiatives are defined and selected” – Bower 1970) . Then, given the specific initiative and its structural context, researchers have advocated that successful execution and profitability depend on elements of the resource allocation process, i.e. who decides what (Bower and Gilbert 2005). In the following three sub-sections we detail these three constructs: the properties of the initiative, the structural context, and the structure of the resource allocation process, respectively. Our objective is to employ these constructs and characterize the value maximizing process choice given an initiative, for a particular firm. Our model setup offers some novel conceptual contributions to the normative organizational design literature, which we highlight in §3.3.5.

⁶Value can be thought of as monetary cash flow, monetary equivalents, e.g. other outcomes such as knowledge, etc.

3.3.1 The NPD initiative.

The initiative is defined by the value it yields, should it realize a successful outcome, and its likelihood of success. Without any loss of generality, we assume that the potential value V is fixed, and known by all of the stakeholders, i.e. the VP and the PM. The probability of success depends on two key factors: the *difficulty* of the tasks required to execute the initiative, and the *resources* allocated to the initiative.

The difficulty of the strategic initiative depends on how arduous the respective tasks are for the project team. In order to fully understand the task details, specialized knowledge is required, which resides with the project team (i.e. project manager). Such knowledge is neither easily communicated (i.e. “transferred”), nor readily understood, by stakeholders who are *not* intimately involved with the execution of the specific tasks. Thus, the VP cannot understand the intricate details of the initiative. Let θ_i , $i \in \{d, e\}$ represent the difficulty of the initiative specific tasks, where $\theta_i \in [0, 1]$. An initiative with $\theta = 0$ represents an impossible task, and $\theta = 1$ represents tasks that have the highest chance of success for a given resource level allocated to them. A-priori the difficulty is unknown to both stakeholders, however prior to the execution of the initiative, the project manager learns θ (while the VP does not). As such, θ is own private knowledge held by the project manager. The initiative may realize a difficult set of tasks for the project team ($\theta = \theta_d$), or an easier – more standard – set of tasks $\theta = \theta_e$, which we normalize to be $\theta_e = 1$. We refer to this type of initiative as one that is *standard* for the organization.

If R represents the decision regarding the level of resources allocated to the initiative, then the likelihood that the firm realizes the project value V , is defined as $p[\theta, R] = \theta P[R]$. We assume $p[\theta, R]$ to be quasi-concave and super-modular in θ and R . More specifically: $\partial p / \partial R > 0$, $\partial p / \partial \theta > 0$, $\partial^2 p / \partial R^2 < 0$, $\partial^2 p / \partial \theta^2 \leq 0$,

$\partial^2 p / (\partial R \partial \theta) > 0$, and $\lim_{R \rightarrow \infty} p[\theta_d, R] < \lim_{R \rightarrow \infty} p[\theta_e, R]$, where $\lim_{R \rightarrow \infty} p[1, R] = 1$. Our structural assumptions regarding $p[\theta, R]$ represent a set of intuitive properties: the likelihood of success is increasing in both the resources allocated to the initiative, and the ease with which tasks can be accomplished for each given resource level; there may be diminishing returns to the likelihood of success resulting from the resources allocated to the initiative, as well as the ease to which the tasks can be accomplished; finally the resources allocated, and the ease by which the tasks are executed, are complementary inputs to the likelihood of success. Indeed, more difficult initiatives require a disproportionately higher level of resources to achieve a given likelihood of success. Furthermore the most difficult initiatives may never have the same likelihood of success as a more standard one, regardless of the level of resources allocated to it. Since the likelihood is endogenously determined by the allocated resources, the structural context, within which resource decisions are made, is essential to understand.

3.3.2 Structural context.

There are two key elements that comprise the structural context in our model: first, the degree of information asymmetry that exists between the VP and the project manager (the stakeholders); second, the organizational norms that govern the implicit rules and expectations regarding “how things are done”, namely the organizational penalties imposed upon managers who fail to complete the strategic objectives⁷.

We begin with a closer look at the information asymmetry. The project manager holds private knowledge regarding the actual difficulty of the required project tasks. As such, he knows θ , yet the VP only knows that θ may be difficult (θ_d) with

⁷Note that the compensation and incentives might be considered part of the structural context, yet they could be adjusted within the context of a resource allocation process. Thus, we choose to discuss them together with the decisions regarding the resource allocation process in §3.3.3. In contrast, we posit that it is rarely the case that organizational norms can be altered within the scope of a single initiative.

probability q and easy ($\theta_e = 1$) with probability $(1 - q)$. This intentional misalignment regarding the knowledge of task execution effectively captures an important reality of the NPD context. Specialists hold competencies that are hard to imitate, let alone replicate. This reality has been argued to lead to hierarchies in the first place (Zingales and Rajan 2001).

Organizational rules implicitly govern how things get done. Such (usually non-codified) rules comprise an organization’s *corporate culture* (Kreps 1990, Hermalin 2008, Chao et al. 2009, Schein 2010). In our context we focus on a particularly important “rule”, namely what happens to the project manager if an initiative fails? There is ample evidence that organizations differ, in the consequences they impose, regarding such outcomes (e.g. a diminished intra-organizational status, reflected in the career paths or development programs the manager is considered for). This dimension of a firm’s “tolerance for failure” that we consider has recently drawn attention as an important determinant of task execution (Manso 2010). Drawing upon several interviews with senior NPD managers, we have found that such consequences are strongly associated with the resources allocated to the initiative (R). Even in a harsh corporate environment, an initiative that fails, yet consumes negligible resources, would not warrant detrimental consequences for the PM’s career. However, for an initiative that consumes copious amounts of organizational resources, and fails, we would expect the consequences to proportionally be much greater. We capture the resource dependence of this organizational effect through a linear parametrization of the penalty: $k_p R$; k_p is exogenously fixed for a specific organization, and as a dimension of the corporate culture, it reflects implicit policies, or accepted routines that are hard to change, at least within the context of a single initiative. In §3.3.4, we discuss how this organizational penalty factors into the overall utility of the project manager.

3.3.3 The resource allocation process (RAP)

Given the definition of the initiative itself (3.3.1), and the structural context (3.3.2), the VP considers the appropriate resource allocation process to use in order to maximize the organization's profits. The choice of the "right" process takes the previous constructs into account in order to determine which stakeholder should be granted decision rights to determine the resource level, and how the VP should influence this decision, should she choose to delegate decision rights (Bower and Gilbert 2005)?

The VP assigns the strategic initiative when she expects the firm to receive value at least equal to $\hat{\Pi}$. The expected value to the VP is $\mathbb{E}[\Pi] = p[\theta, R]V - R - W$, or the expected revenue of the project ($p[\theta, R]V$), net of expenses associated with the allocation of resources (R), and wages (W) required to execute it. Yet, as we have described in 3.3.1, the likelihood of success is not an exogenously specified quantity, but a function of the resources allocated and the difficulty of the execution tasks. In addition, the VP does not know the latter with certainty. Under such circumstances, the VP can choose to enlist the detailed knowledge (project difficulty) of the PM, and delegate the resource allocation decisions to him, which we define as a *bottom-up* resource allocation process; or she can dictate the exact resource budget, which we define as a *top-down* resource allocation process. Changes in how resources are allocated might also warrant changes to the compensation structure, W , as well. Let $W[w, k_s] = w + k_s(V - R)$, represent a generic form of compensation offered to the PM; it is a combination of a fixed wage w portion and an output contingent profit-share mechanism, $k_s(V - R)$. Our analysis determines which parts of such generic compensation are rendered inactive, i.e. $w = 0$ or $k_s = 0$, under different choices of RAP. Regardless of whether the VP chooses a top-down or a bottom-up resource allocation process, she must set compensation so that the project manager does not ex-ante expect to suffer a loss from undertaking the initiative. In other words, the PM expects to at least earn a level of utility equal to his opportunity cost (\underline{U}); which,

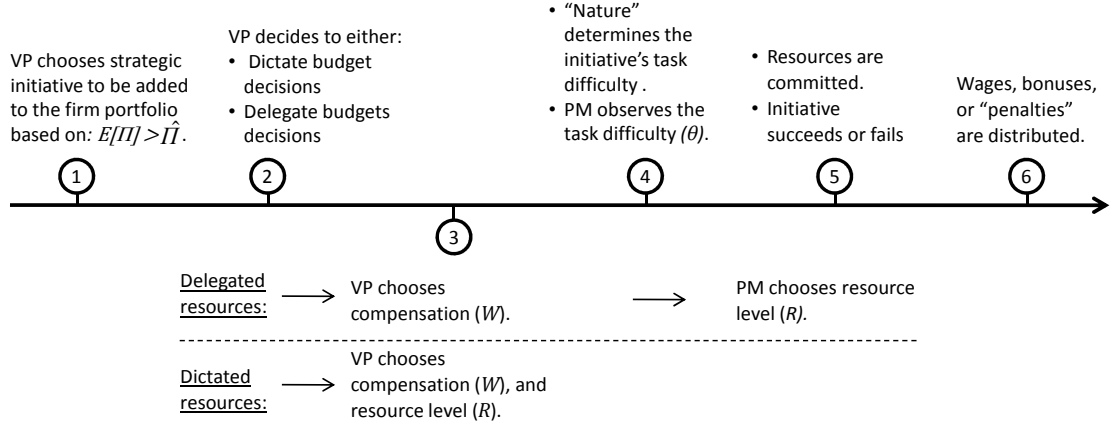


Figure 6: The sequence of events and related decisions.

without loss of generality, we normalize to zero (Baiman and Rajan 1995)⁸.

The following two important observations drawn from field studies support our assumptions regarding the resource allocation process: i) the PM is always given formal authority (Aghion and Tirole 1997) to recommend the initiative not be funded (i.e. alternatively, they are allowed to “opt-out”) – the expectation is that they do so when their outside option (\underline{U}) is not met on expectation (Baiman and Rajan 1995)⁹; ii) the VP can not determine (or verify) the true underlying task difficulty (i.e. θ is not directly contractible) regardless of the outcome (success or failure), i.e. the contract is incomplete.

⁸The opportunity cost of the PM is common knowledge. The interpretation is intuitive: embedded in the opportunity cost is the benefit the PM can receive, net of switching costs, if they were to choose alternate employment. This simply captures the intuitive realization that, if you put a PM on a project where their exposure to failure is simply too high (and the resulting penalties too harsh), they would rather seek out alternative opportunities than risk having their career prospects severely impacted.

⁹Note, we claim that the VP expects the PM to “opt-out” if their outside option is not met. To see this imagine that the VP only wanted to pursue simpler initiatives. Since she could not a-priori know what the difficulty is, nor could she ex-post confirm it, the only way she could achieve this would be to design compensation such that the PM opts-out of initiatives when he realizes difficult execution tasks. If the PM were *not allowed* to opt-out, then the VP could not achieve this.

We present the sequence of decisions, and the timing of information in Figure 6. The sequence reflects our own anecdotal evidence, but also rests upon the extensive volume of field studies conducted by researchers of Strategic Management (Bower and Gilbert 2005).

3.3.4 The feasible set of initiatives and stakeholder utilities

Now that we have discussed the main conceptual elements of our model, we formally define the expected profit of the VP, the expected utility of the PM, and each stakeholder's respective maximization objective.

Definition 3. THE EXPECTED PROFIT OF THE VP AND UTILITY OF THE PROJECT MANAGER.

The VP's problem is as follows:

When resources are dictated:

$$\begin{aligned} \max_{R, W} \quad & \mathbb{E}[\Pi] = \mathbb{E}_\theta[\theta P[R]V - R - W] \\ \text{s.t.} \quad & \mathbb{E}[U|\theta] = W - (1 - \theta P[R])k_p R \geq \underline{U} \\ & \mathbb{E}[\Pi] \geq \hat{\Pi} \end{aligned}$$

When the PM is fully empowered:

$$\begin{aligned} \max_W \quad & \mathbb{E}[\Pi] = \mathbb{E}_\theta[\theta P[R_\theta]V - R_\theta - W[R_\theta]] \\ \text{s.t.} \quad & \mathbb{E}[U|\theta] = W[R_\theta] - (1 - \theta P[R_\theta])k_p R_\theta \geq \underline{U} \\ & \mathbb{E}[\Pi] \geq \hat{\Pi} \\ & R_\theta = \arg \max_{R_\theta} W[R_\theta] - k_p(1 - \theta P[R_\theta])R_\theta \end{aligned}$$

Having stated each stakeholder's utility and objective function, we explain how the structural context and the resource allocation process impact the initiatives that the firm decides to fund, i.e. those strategic initiatives where $\mathbb{E}[\Pi] \geq \hat{\Pi}$. We define the *feasible set of initiatives* as those initiatives for which $\mathbb{E}[\Pi] \geq \hat{\Pi}$, for a given resource allocation process, and structural context; thus, the feasible set contains the initiatives the VP is willing to fund. Ceteris paribus, a smaller feasible set of

initiatives can be interpreted as a smaller set of opportunities within which the firm can seek profit. This conceptualization of the feasible set of initiatives, given the organizational context, is an analog to Markowitz’s (1952, p. 85) “attainable set” of investments given a specific individual investor. Markowitz explains that there is no single attainable set of investments for all investors, but that the set of attainable investments depends on the individual’s risk preferences. Our analysis considers how a firm’s organizational context and its resource allocation process impact its set of feasible initiatives.

3.3.5 Summary of conceptual contributions

Prior to our analysis, we provide a brief discussion of the conceptual contributions and key distinctions of our model. In summary, our model formulation captures the following salient features of the NPD context:

- The knowledge that is required to make critical funding decisions is dispersed among various stakeholders resulting in distinct information asymmetries within the organizational hierarchy. In that respect, it is impossible to ex-post identify the specific “cause” of the success or failure of an initiative (i.e. insufficient resources or a random outcome).
- The utility functions of the stakeholders are risk neutral. Our assumption aims to avoid any *a priori* risk bias. We do this to isolate potential organizational effects, as opposed to relying upon explanations based on individual behavioral traits, a usual justification for an organization’s avoidance of risky initiatives (Hauser 1998).
- Most traditional agency models assume managerial risk aversion, and a disutility from personal effort to justify both an organization’s tendency to forego difficult initiatives and their use of output contingent compensation. Instead,

we show that the nonlinear returns from a NPD initiative and the existence of organizational penalties represent an alternative rationale.

- The only private component in the project manager’s objective is his knowledge of the true difficulty the initiative represents θ . Given such a formulation, we avoid any a-priori misalignment between the payoffs to the stakeholders, another highly cited reason for many organizations’ failure to pursue risky initiatives (Siemsen 2008, Manso 2010, Mihm 2010). In our model, the “alignment”¹⁰ between the VP and the PM’s objective lies within the VP’s discretion.
- Lastly, we recognize the complementarity between project type (i.e. task difficulty) and the resources allocated. Such complementarities stem from the fact that NPD initiatives exhibit complex interactions, such that marginally increasing difficulty along any single dimension could imply a disproportionate increase in the resources required to achieve the same likelihood of success.

3.4 *Analytic results*

In this section we present the results of our model analysis. Recall that, we aim to answer the following question: When is it better to have a process that delegates the resource allocation decision? We start with the first-best outcome, i.e. all stakeholders know the true difficulty of the initiative. The first-best outcome allows us to establish a baseline result, and to develop key metrics and intuition. We then move to the more realistic setting where information asymmetries exist regarding the initiative difficulty. Within such a setting, we first analyze a top-down resource allocation process, and then we contrast this analysis with the results from the bottom-up process where the PM is *fully empowered*. Following our comparison, we seek to identify a RAP that

¹⁰We define *alignment* strictly in terms of the objectives of each stakeholder (in line with prior literature, see Van Den Steen 2007). The stakeholders are aligned when their optimal actions yield the same solutions.

mitigates the challenges associated with either the top-down or bottom-up process. We find that if we relax the assumption that requires the organization to apply a uniform compensation scheme (i.e. w and/or k_s are independent of θ), and instead allow the firm to offer the PM a choice between pre-defined resource levels, where each resource level is coupled with a different compensation scheme (i.e. an “incentive feasible menu of contracts”), then we can achieve a RAP that outperforms both the top-down and bottom-up processes for all levels of expected difficulty. We discuss the limitations of such a process in practice, as identified by the prior literature, and we point out that a simplified version of such a RAP can (weakly) supersede the traditional top-down and bottom-up processes. Eventually, we point out that this simplified version resembles and justifies the widely used practice of resource allocation via “strategic-buckets”.

3.4.1 Baseline: First-best solution

We begin our model analysis with a look at the first-best setting, where no information asymmetries exist. The difficulty of the initiative is known to all stakeholders. In this setting, for an initiative of known type θ , the optimal choice for the VP is to determine resource levels and ensure implementation through the use of a fixed wage compensation plan. We formally state these results below and defer the proofs to the appendix, for clarity of exposition.

Proposition 6. FIRST BEST RESOURCE ALLOCATION AND THE FEASIBLE SET.

(a) *The optimal resource level R^{fb} solves: $\partial P[\cdot]/\partial R = (1 + k_p(1 - \theta P[R]))/(V + k_p R)$*

and it is increasing in the ease of the project tasks θ , i.e. $\partial R^{fb}[\cdot]/\partial \theta > 0$

(b) *The feasible set of initiatives is defined by:*

$$\mathcal{F}^{fb} \doteq \left\{ \theta \geq \hat{\theta}, \hat{\theta} \text{ solves } P[R^{fb}] = \frac{(\hat{\Pi} + 1 + k_p)R^{fb}}{\theta(V + k_p R^{fb})} \right\} \text{ and } \mathcal{F}^{fb} \text{ increases as } \theta \text{ increases.}$$

The first-best resource level has an economic interpretation. For each additional unit of resources the VP allocates, the probability of success p increases, $(V - R)$ decreases, and the managers face a larger penalty $k_p R$ should the project fail. The optimal resource allocation equates marginal expected value from each additional unit of resource, to the marginal cost of compensation the VP must bear to cover the PM's the potential organizational penalty. Beyond this resource level, any marginal value gained from an additional resource ($V\partial P[\cdot]/\partial R - 1$) is outweighed by the marginal wages ($k_p(1 - P[\cdot] - R\partial P[\cdot]/\partial R)$) required to offset the potential penalty faced by the managers.

As θ decreases (i.e. more difficult tasks), the optimal level of resources decreases. The result stems from the assumed complementarity between the task difficulty and the resources allocated. Finally, we outline the baseline feasible set of initiatives.

3.4.2 A resource allocation process that maintains control

In a top-down resource allocation process, the VP dictates the level of resources, and the compensation plan. In such a setting, the VP needs to ensure that the compensation offered to the project manager provides him with an expected utility at least equal to his reservation utility, regardless of the realization of the initiative's difficulty. The following proposition outlines the implications of implementing a top-down resource allocation process.

Proposition 7. A TOP-DOWN RESOURCE ALLOCATION PROCESS AND ITS FEASIBLE SET. *The following statements hold when the VP chooses a top-down resource allocation process:*

(a) *The VP offers compensation in the form of a fixed wage.*

$k_s^* = 0$ and $w^* = k_p R^* (1 - \theta_d P[R^*])$, where R^* is the optimal level of resources.

(b) *The optimal level of resources R^* solves:*

$$1 + k_p(1 - \theta_d P[R]) - \frac{\partial P[R]}{\partial R} (k_p dR - V\mathbb{E}[\theta]) = 0, \text{ is increasing in } \theta_d, \text{ i.e. } \frac{\partial R^*}{\partial \theta_d} > 0$$

and it is strictly less than the first-best, i.e. $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$

(c) $\mathcal{F}^{td} \doteq \left\{ \mathbb{E}[\theta] : \mathbb{E}_\theta[\Pi] \geq \hat{\Pi} \right\}$, $\mathcal{F}^{td} \leq \mathcal{F}^{fb}$, and \mathcal{F}^{td} gets smaller as k_p increases.

When the resource levels are dictated to the project manager, it is suboptimal to use compensation schemes that are contingent on the outcome. If the VP were to use output contingent compensation with an incentive parameter k_s , then in the event the PM realizes θ_e , i.e. a standard project, he is disproportionately (over) compensated¹¹, and increases the firm's loss. This loss is a result of the complementarity between θ and R . It follows that it is better for the firm to avoid such a loss by offering a fixed wage.

Next, we compare the VP's resource allocation decision when she does not know the actual difficulty, and only knows $\mathbb{E}[\theta] = q\theta_d + (1 - q)\theta_e$ (i.e. under asymmetric information), with the decision she would make if she knew (with certainty) that $\theta = q\theta_d + (1 - q)\theta_e$ (i.e. the first-best decision for θ). This comparison reveals that as long as *some* level of asymmetry exists ($q \neq \{0, 1\}$), the resources assigned under asymmetric information are always less than the first-best level. This results from the VP's need to offset a more costly expected penalty, i.e. $(1 - \theta_d P[R])k_p R > (1 - \mathbb{E}[\theta]P[R])k_p R$ in order to ensure that the initiative is executed. The difference between the optimal resource allocation under a top-down RAP and that of the first-best setting, is moderated by both the organizational penalty k_p and the expected difficulty $\mathbb{E}[\theta]$. Again, this is a direct result of the VP's inability to know the PM's expected penalty for a given resource level, and her need to tailor the resource allocation to the worst case scenario, θ_d . In a harsher organization, the VP must account for a

¹¹We elaborate on the use of the term "disproportionately": it is true that regardless of the compensation scheme, a PM who realizes θ_e will always be overcompensated (in the sense that they expect to earn $U > \underline{U}$); when an output contingent compensation scheme is used, the surplus the PM expects to earn is even greater compared to the surplus expected with a fixed wage.

higher k_p which results in a greater loss due to the firm leaving additional surplus for the PM who realizes θ_e . Overall, for initiatives that encompass more difficulty than is usually undertaken (unfamiliar task domains), the VP ends up significantly under-investing resources when employing a top-down RAP.

A critical implication of the information asymmetry is whether the VP deems it worthy to fund the initiative. Our analysis highlights the fact that projects live and die by how well understood they are by the stakeholders of the firm (Bower 1970). Whereas in the first-best θ was known and we defined \mathcal{F}^{fb} in terms of θ , for the top-down RAP we define the feasible set of initiatives \mathcal{F}^{td} in terms of the expected difficulty $\mathbb{E}[\theta]$, and compare it to \mathcal{F}^{fb} . The feasible set of initiatives shrinks when the stakeholders are more asymmetrically informed for a given set of task difficulties. Although our result is intuitive, it is valuable to understand both how and why it occurs. What drives fewer initiatives to be funded? As we have discussed, the VP under invests ($R^* < R^{fb}$) in order to ensure that even when the PM realizes θ_d , he still is sufficiently compensated (i.e. his reservation utility is met). The necessity to compensate the project manager for a θ_d realization impacts the VP in two ways: not only does a lower θ_d exaggerate the under-investment, but it also drives the VP to compensate the PM beyond what he might require when undertaking a θ_e set of tasks. The former implies that the overall profits generated will be less on expectation, while the latter allows the PM to appropriate a greater portion of the profits that are generated. Ultimately, initiatives that were deemed worthy of funding under a first-best scenario, no longer are. This effect gets exacerbated in the context of an organization with a low tolerance for failure (high k_p). Organizations that impose harsh penalties for failed initiatives, significantly reduce their feasible set of initiatives. Less projects meet the $\hat{\Pi}$ criteria required for the firm to fund them. When the result is thought of in terms of a firm's overall ability to innovate, any reduction to the feasible set can have a significant impact on the firm (Kornish and

Ulrich 2010). To see this, think of the feasible set as an opportunity set. Limiting the set of feasible initiatives amounts to limiting the opportunities for the organization; a result most firms would rather avoid.

3.4.3 A resource allocation process that empowers the project manager

We now examine the situation where the VP delegates the decision rights (Aghion and Tirole 1997) regarding the resource levels and delegates such a decision to the project manager (i.e. a bottom-up resource allocation process). The extant Strategic Management literature advocates the value of such delegation (Bower and Gilbert 2005). In such a setting, the only decision made by the VP is to set the compensation such that the project manager executes the initiative (i.e. does not exercise his authority to opt-out of particular initiatives) regardless of θ .

Proposition 8. THE FULL-EMPOWERMENT RESOURCE ALLOCATION PROCESS. *The following statements hold when the VP chooses a full-empowerment resource allocation process:*

(a) *The VP offers compensation that is contingent on outcome:*

$$w^* = 0 \text{ and } k_s^* = \frac{k_p R^*[\theta_d](1 - \theta_d P[R^*[\theta_d]])}{(V - R^*[\theta_d])\theta_d P[R^*[\theta_d]]}$$

(b) *The PM allocates resource levels*

$$R^*[\theta_d] \text{ that solves } \frac{\partial P[R^*[\theta_d]]}{\partial R} = \frac{VP[R^*[\theta_d]](1 - P[R^*[\theta_d]]\theta_d)}{(V - R^*[\theta_d])R^*[\theta_d]}$$

$$R^*[\theta_e] \text{ that solves } \frac{\partial P[R^*[\theta_e]]}{\partial R} = \frac{P[R^*[\theta_e]](VP[R^*[\theta_d]]\theta_d - R^*[\theta_d]) - P[R^*[\theta_d]]\theta_d(V - R^*[\theta_d])}{R^*[\theta_d](V(1 - P[R^*[\theta_d]]\theta_d) - R^*[\theta_e]) + VP[R^*[\theta_d]]\theta_d R^*[\theta_e]}$$

(c) *When $\theta_d = \frac{(1+k_p)R^{fb}[\theta_d]}{(k_p R^{fb}[\theta_d] + V)P[R^{fb}[\theta_d]]}$, the resource level chosen by the project manager is equal to the first-best resource level.*

(d) *The set of feasible initiatives is: $\mathcal{F}^{fe} = \left\{ \mathbb{E}[\theta] : \mathbb{E}[\Pi] \geq \hat{\Pi} \right\}$. $\mathcal{F}^{fe} < \mathcal{F}^{fb}$, and gets smaller as k_p increases.*

In contrast to the top-down resource allocation process, under full-empowerment, the VP is strictly better off by implementing an output-contingent compensation scheme¹². Since, the only cost faced by the PM is the potential organizational penalty $k_p R$, the VP must offer output-contingent compensation to induce the project manager to allocate any resources at all. If a fixed wage were offered to the project manager, then regardless of θ , he would be better off allocating the minimum level of resources ($\epsilon \rightarrow 0$). In other words, a fixed wage yields the PM w with certainty when the minimum level of resources are allocated, whereas if the PM allocates significant levels of resources ($R > \epsilon$), at best he can earn w , but he faces $w - k_p R$ with some positive probability. Thus, if the PM is given full-empowerment after receiving a fixed wage, he has minimal incentive to allocate resources. Instead, with an output-contingent compensation, the project manager faces the following trade-off: he increases the resources allocated in order to increase likelihood of success $P[R]$, and decrease the likelihood of a penalty; yet, he needs to limit the resources allocated in order to preserve the profit, $V - R$ and limit the penalty $k_p R$ should the initiative fail. To accomplish the optimal balance, the project manager accounts for his private information and decides on the resources allocated accordingly. Then, the VP sets the compensation such that the PM executes the initiative (with a non-zero resource allocation), regardless of the difficulty. This translates into an incentive parameter designed for θ_d .

Once the compensation is set, the project manager's decision is solely affected by the relationship between the share of profits (k_s) and the harshness of the penalty (k_p). Note that, neither the PM's resource level choice, nor the VP's incentive choice is affected by the likelihood of the different difficulty realizations (i.e. q); only the expected profits are affected. The manager is unaffected by q , as he makes his decision

¹²The VP designs compensation to ensure that the reservation utility is met for all initiatives she funds. Recall, the PM is risk neutral and his reservation utility is equal to zero.

under full knowledge of the difficulty. The VP need not account for q in her choice of incentive since she knows that the project manager is unaffected by it, and the fact that she designs the incentives solely with the most difficult realization in mind, θ_d , not the likelihood that such a difficulty realizes.

Interestingly, it is possible to achieve the first-best level resource allocation when the VP delegates the resource allocation decision. Furthermore, the firm can attain a resource allocation of $R^{fb}[\theta]$ under full-empowerment for both θ_d and θ_e , when the firm's expected difficulty meets the condition outlined in Proposition 8 (c). Why does this happen for both difficulty realizations? Recall that under full-empowerment the PM sets the resource levels with full knowledge of the task difficulty θ for a given incentive k_s . The incentive parameter is set based on θ_d , and it is independent of the resources allocated under a θ_e realization. Said differently, regardless of the realization of θ , the PM receives the same share of profits should the initiative succeed. Similarly, the magnitude of k_p independent of the difficulty realization. Knowing that the PM's resource allocation decision is driven by k_s and k_p , and that both are independent of θ , we can define a relationship between k_s and k_p such that the objectives of the firm and those of the PM are aligned. Then, R^{fb} can be achieved regardless of θ , by empowering the PM. Below, we outline the implications for the choice of RAP resulting from this ability to achieve such alignment between the VP and the PM.

Proposition 9. WHEN FULL-EMPOWERMENT DOMINATES A TOP-DOWN PROCESS.

For an organization with $k_p < \bar{k}_p$:

- (a) *A top-down resource allocation process yields a higher profit for initiatives with low expected difficulty (i.e. as $E[\theta] \rightarrow 1$).*
- (b) *A full-empowerment resource allocation process yields higher profit than a top-down resource allocation process for initiatives in the interval $[\theta_\ell, \bar{\theta}]$.¹³, where*

¹³Let the superscripts *td* and *fe* denote top-down and full-empowerment respectively. Then for

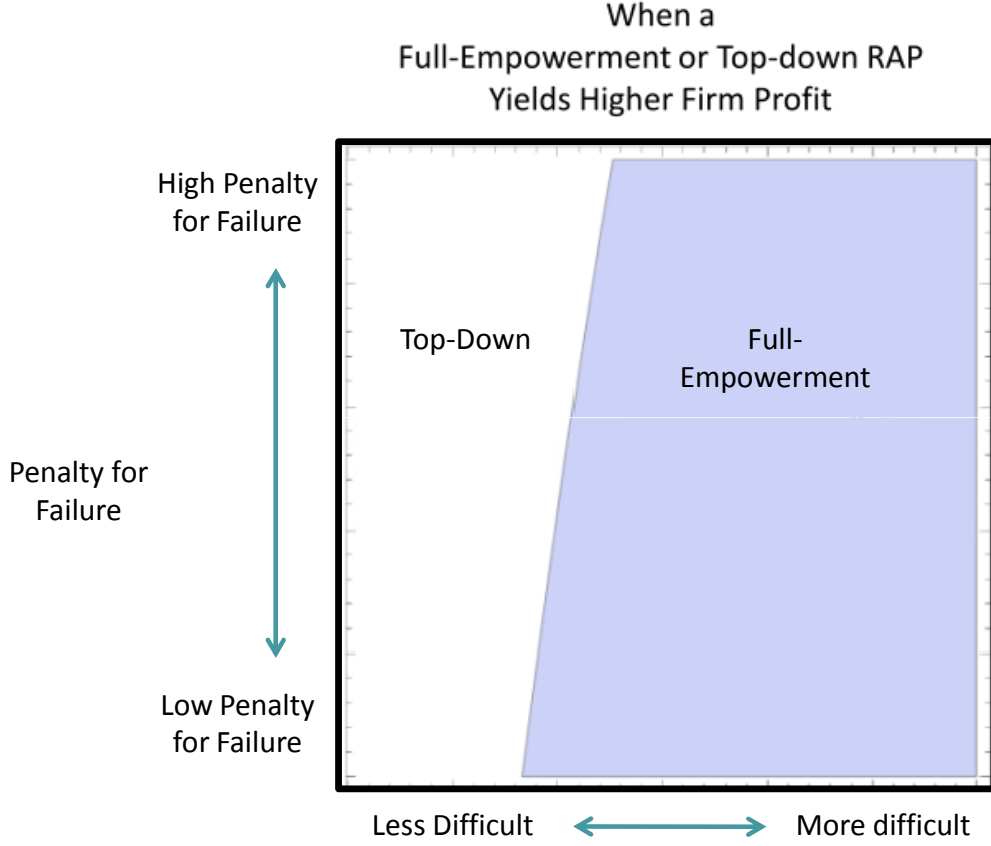


Figure 7: Resource allocation under full-empowerment and top-down resource allocation processes.

$$\theta_\ell < \frac{(1+k_p)R^{fb}[\theta_d]}{(k_p R^{fb}[\theta_d] + V)P[R^{fb}[\theta_d]]} < \bar{\theta} \text{ and } q > \hat{q}$$

- (c) A top-down process always dominates a full-empowerment resource process for sufficiently high $\hat{\Pi}$ (and the feasible set is always smaller with a full-empowerment resource process).

Proposition 9 elaborates on the inherent trade-offs between the type of resource allocation process used, and the profitability objectives of the firm. No resource allocation process strictly dominates in all possible situations. The finding lends

the crossing points between the profit functions $\Pi^{td}[\theta]$ and $\Pi^{fe}[\theta]$ as shown in the proof of Theorem 9 if $\hat{\theta} : \Pi^{fe}[\hat{\theta}] = 0$, the lower threshold on the interval of Theorem 9 (b) is $\theta_\ell = \max\{\hat{\theta}, \underline{\theta}\}$.

normative support to Burgelman’s (1983) claim that organizations need to employ multiple processes for innovation, an observation also presented recently by Chao and Kavadias (2009). Thus, it is important to understand when each resource allocation process is most appropriate. Intuitively, when the initiative is fairly standard (i.e. $E[\theta] \rightarrow \theta_e = 1$), the firm expects to earn greater profits by dictating the resource level. This is a clear situation where the VP benefits from efficiency and control. In such cases, the VP knows the difficulty of the undertaking with relative accuracy, and thus the value of the private knowledge of the project manager is diminished. However, as $\mathbb{E}[\theta]$ decreases (either because the asymmetry between the stakeholders increases, or the initiative has a lower θ_d), the value of the project manager’s private knowledge increases. In Proposition 8 we argued that the incentives offered to the project manager can induce him to make the first-best resource allocation. Given this observation, the only loss to the VP results from the need to use an outcome contingent incentive k_s , which yields less profit as compared to the use of a fixed-wage. Such a loss, increases in the magnitude of k_p (Proposition 7) such that for low enough k_p the compensation loss is dominated by the gain in expected overall profit due to the first-best resource allocation. In the end, the loss from the outcome contingent compensation is mitigated when k_p is relatively low (i.e for organizations that are not severely harsh) and the context is one of high asymmetry and difficulty, where the gains are larger from obtaining the first best resource allocation. In other words, under such settings the organization can successfully fund and execute high difficulty initiatives (such as developing a radically new technology or entering an entirely new market).

Finally, we turn to the VP’s criteria for funding initiatives. As the VP’s threshold ($\hat{\Pi}$) becomes higher (e.g. resulting from high value alternatives considered for the firm’s portfolio), the VP does two things: restrict the overall feasible set of initiatives

(as shown in Proposition 6), and renders a full-empowerment process inferior to a top-down process for all feasible initiatives. Taken together these results have powerful managerial implications as they highlight the need for multiple processes *within a single firm*. A firm that only employs a single RAP does itself an injustice: solely implementing a top-down process means a reduction in the feasible set, i.e. the firm foregoes initiatives that would otherwise be profitable under a fully empowered RAP (i.e. initiatives where $\mathbb{E}[\Pi^{fe}] \geq \hat{\Pi}$ but $\mathbb{E}[\Pi^{td}] < \hat{\Pi}$); yet, solely implementing a fully empowered RAP means foregoing profits for those initiatives that are more standard.

3.4.4 A resource allocation process that allows “empowerment” *and* “control”?

Thus far we have presented two resource allocation processes that highlight the trade-off between, the *control and efficiency* gained by a central choice of the resource budgets along with the compensation and the *effective use of knowledge*, that comes from empowering the project manager to tailor resource levels to the difficulty of the initiative. In that light, the lack of any single process to outperform the other in all settings opens up a question of whether it is possible for the VP to maintain *some* control, and the associated efficiency benefits, while empowering the PM to have *some* influence on what the resource levels should be, and thus reap benefits from the PM’s expertise.

In this section we analyze whether the firm can accomplish such a balance between control and empowerment. We seek to identify whether a RAP exists that offers an optimal mechanism¹⁴, i.e. the firm does better than under either the top-down or full-empowerment approaches. We show that such a process must depart from the assumption that the compensation scheme must be universally applied in a “fair” manner, regardless of the difficulty of the initiative (Baker et al. 1988, Fehr et al.

¹⁴Otherwise said, we seek to determine whether it is possible to define a mechanism where the VP offers specific contracts–resource levels and compensation– that induce the PM to reveal the true project type (i.e. a fully separating equilibrium).

2007). In other words, compensating the PM through a profit-sharing bonus is not sufficient to get the “best” allocation (i.e. most effective use of his knowledge); the bonus would need to be tailored to the initiative. Below we formally define such a process for each of the stakeholders.

Definition 4. A RESOURCE ALLOCATION PROCESS UTILIZING AN OPTIMAL MECHANISM. *The VP maximizes her expected profit:*

$$\begin{aligned}
& \max_{R_{\theta_d}, R_{\theta_e}, W_{\theta_d}, W_{\theta_e}} \mathbb{E}[\Pi] = \mathbb{E}_{\theta}[\theta P[R_{\theta}]V - R_{\theta} - W_{\theta}] \\
& s.t. \\
& (i) \quad \mathbb{E}[U|\theta_d, R_{\theta_d}, W_{\theta_d}] \geq \underline{U} \\
& (ii) \quad \mathbb{E}[U|\theta_e, R_{\theta_e}, W_{\theta_e}] \geq \underline{U} \\
& (iii) \quad \mathbb{E}[U|\theta_d, R_{\theta_d}, W_{\theta_d}] \geq \mathbb{E}[U|\theta_d, R_{\theta_e}, W_{\theta_e}] \\
& (iv) \quad \mathbb{E}[U|\theta_e, R_{\theta_e}, W_{\theta_e}] \geq \mathbb{E}[U|\theta_e, R_{\theta_d}, W_{\theta_d}]
\end{aligned}$$

A resource allocation process that tailors both resources and compensation to the potential difficulty realizations (via an incentive feasible Bayesian mechanism), requires a disclaimer: portraying such a process at parity with the prior processes ignores the additional complexities and the (potentially prohibitive) costs associated with implementing such an involved scheme (see Mihm 2010 for a discussion of the complications associated with implementing incentive feasible, Bayesian mechanisms in practice)¹⁵. Below we formally present the optimal resource allocation process.

Proposition 10. THE OPTIMAL RESOURCE ALLOCATION PROCESS. *The following statements hold when the resource allocation process entails the VP tailoring both resource allocations and compensation:*

¹⁵To capture such added complexity and cost we can simply append a cost c to the objective function, and as we explain in Proposition 11, such an addition gives rise to situations where it is not optimal to employ such a process.

(a) The output contingent portion of the compensation is always set to zero ($k_s^* = 0$).

(b) The VP defines two options with the following properties:

$(w_{\theta_d}^*, R_{\theta_d}^*)$, and $(w_{\theta_e}^*, R_{\theta_e}^*)$ that satisfy:

$$(i) \ w_{\theta_d}^* = k_p R_{\theta_d}^* (1 - \theta_d P[R_{\theta_d}^*])$$

$$(ii) \ w_{\theta_e}^* = k_p (P[R_{\theta_d}^*] R_{\theta_d}^* (\theta_e - \theta_d) + R_{\theta_e}^* (1 - P[R_{\theta_e}^*] \theta_e))$$

$$(iii) \ R_{\theta_d}^* \text{ solves } P[R_{\theta_d}] = \frac{q(1-V\theta_d P'[R_{\theta_d}]) + k_p(q - R_{\theta_d}(\theta_d - (1-q)\theta_e)P'[R_{\theta_d}])}{k_p(\theta_d - (1-q)\theta_e)}, \text{ where } R_{\theta_d} < R^{fb}[\theta_d]$$

$$(iv) \ R_{\theta_e}^* = R_{\theta_e}^{fb}$$

In an optimal RAP, fixed wages outperform any output-contingent compensation. The logic is similar to our discussion in Proposition 7. The VP's goal when implementing such a resource allocation process is to categorize the initiatives, in order to set the appropriate resource levels, and therefore, extract maximum surplus through the use of tailored compensation. To accomplish her objectives, the VP designs and offers a resource level and compensation that strictly adhere to the conditions outlined in of Proposition 10 (b). These conditions accomplish the aforementioned objectives as follows: for the most difficult initiatives (θ_d), the resource levels and wages offered, are such that the project manager only expects to meet his reservation utility, whereas a PM who realizes task difficulty θ_e , earns a surplus (on expectation). If the VP tried to extract the full surplus from simpler, i.e. standard initiatives, such that the PM only expected to receive his reservation utility, then the PM would choose the resource level and compensation scheme designed for the difficult one (and earn a surplus)¹⁶. As such the VP (by necessity) leaves some surplus for the PM.

¹⁶There is another option that would force the PM to execute the standard initiative (θ_e) and be forced to his reservation utility. For such cases the VP purposefull designs the RAP to induce the PM to opt-out of difficult initiatives and as a result the PM *only* undertakes standard initiatives. We choose not to focus on those cases as they are counter to our focus on understanding resource allocation processes that allow organizations to undertake initiatives with expected difficulty $\mathbb{E}[\theta]$ regardless of the actual realization of the difficulty.

As advocated by recent studies in the NPD literature (Mihm 2010) and the Economics literature (Baker et al. 1988, Fehr et al. 2007), the implementation of such complex incentive mechanisms may entail an additional direct or indirect cost c , which may render them infeasible or undesirable. Proposition 11 below establishes that provided the magnitude of c is small enough, the optimal mechanism remains beneficial for initiatives with substantial expected task difficulty (i.e. low enough $E[\theta]$).

Proposition 11. RESOURCE ALLOCATION PROCESS.

- (i) *When there is no implementation cost associated with implementing tailored compensation schemes and resource allocations, such a process dominates top-down or bottom-up for any $E[\theta]$.*
- (ii) *There exists a cost threshold $\bar{c} \in \mathbb{R}^+$ such that for all $c \geq \bar{c}$ tailored compensation and resource allocations is less profitable than either top-down or full-empowerment.*

The potential issues that relate to the implementation of the optimal mechanism: organizational fairness,¹⁷ cost, and complexity, we ask the question: Is it possible to construct a “next-best” resource allocation process that allows the firm to offer a *universally applied* compensation scheme and *only* vary the resource level that the PM chooses between? Such a process represents a well defined managerial practice referred to as “strategic buckets” (Cooper et al. 2001, Chao and Kavadias 2008, Terwiesch and Ulrich 2009). We formally define such a process below:

Definition 5. A RESOURCE ALLOCATION PROCESS UTILIZING STRATEGIC BUCKETS. *The VP maximizes her expected profit:*

¹⁷We point out that implementing an optimal RAP as proposed *internal* to a single firm, translates to a compensation plan for the PM where his compensation is explicitly contingent on the realization of the project type., which is outside his control and defined at a high level by the VP. Implementing such a plan

$$\begin{aligned}
& \max_{R_{\theta_d}, R_{\theta_e}, W} \mathbb{E}[\Pi] = \mathbb{E}_{\theta}[\theta P[R_{\theta}]V - R_{\theta} - W] \\
& s.t. \\
& (i) \quad \mathbb{E}[U|\theta_d, R_{\theta_d}, W] \geq \underline{U} \\
& (ii) \quad \mathbb{E}[U|\theta_e, R_{\theta_e}, W] \geq \underline{U} \\
& (iii) \quad \mathbb{E}[U|\theta_d, R_{\theta_d}, W] \geq \mathbb{E}[U|\theta_d, R_{\theta_e}, W] \\
& (iv) \quad \mathbb{E}[U|\theta_e, R_{\theta_e}, W] \geq \mathbb{E}[U|\theta_e, R_{\theta_d}, W]
\end{aligned}$$

Recently more firms have adopted a hierarchical resource allocation process, where resources are “earmarked” for a particular *type* of initiative¹⁸. In such a setting, the VP may associate the different difficulty initiatives into specific strategic buckets (e.g. buckets aimed at funding initiatives that strengthen current product lines, or those that stretch the organization into entirely new market segments, see Loch and Kavadias 2010). These practices have been advocated as a means to “protect” resources for a “long enough” period of time so as the firm can undertake radical (difficult) initiatives and see them come to fruition (Chao and Kavadias 2008). Our analysis points to an alternative justification for employing strategic buckets that stems from the need to offer implicit incentives to project managers in order to promote them to make the most effective use of their expertise.

Proposition 12. A RESOURCE ALLOCATION PROCESS THAT USES STRATEGIC BUCKETS. *When the VP chooses to use strategic buckets as the resource allocation process:*

- (a) *The output contingent portion of the compensation is always set to zero ($k_s^* = 0$).*
- (b) *The VP offers strategic buckets with the following properties (where $\theta' < \theta'' < 1$):*

$(w^, R_{\theta_d}^*)$, and $(w^*, R_{\theta_e}^*)$ satisfy:*

¹⁸First hand conversations with executives at Fortune 500 companies have outlined processes whereby they earmark specific funds for specific types of projects.

(i) For $\theta_d \leq \theta'$

$$(a) \ w^* = k_p R_{\theta_d}^* (1 - \theta_d P[R_{\theta_d}^*])$$

$$(b) \ R_{\theta_e}^* (1 - \theta_e P[R_{\theta_e}^*]) = R_{\theta_d}^* (1 - \theta_e P[R_{\theta_d}^*])$$

(ii) For $\theta' < \theta_d \leq \theta''$

$$(a) \ w^* = k_p R_{\theta_d}^* (1 - \theta_d P[R_{\theta_d}^*])$$

$$(b) \ R_{\theta_e}^* = P^{-1}[\frac{1}{V}]$$

(iii) For $\theta_d > \theta''$, $R_{\theta_d}^* = R_{\theta_e}^*$

A strategic buckets allocation process works in concert with the organizational norms (i.e. the penalty for failure) as follows: first, it provides a greater level of resources to θ_e initiatives (i.e. $R_{\theta_e}^* > R_{\theta_d}^*$), such that when coupled with the organizational penalty k_p , accepting an $R_{\theta_e}^*$ allocation when θ_d is realized yields less than the reservation utility for the PM. In other words, the ability to offer distinct resource options creates an implicit “compensation” effect through the organizational norms themselves (and in addition, provides a rationale for such penalties). This allows the VP to adequately tailor the strategic buckets and ensure that the project manager selects the correct one. This is a powerful insight regarding the ability of the firm to define distinct buckets without necessitating distinct and explicit compensation (i.e. wages) to appropriate the benefits. We characterize the benefits below by contrasting the strategic buckets with the top down process.

Proposition 13. THE CHOICE BETWEEN A TOP-DOWN AND STRATEGIC BUCKETS PROCESS.

(i) *There exists a threshold $\hat{\theta}$ such that for all $E[\theta] < \hat{\theta}$, the profits from implementing a strategic buckets process dominate those under a top-down resource process.*

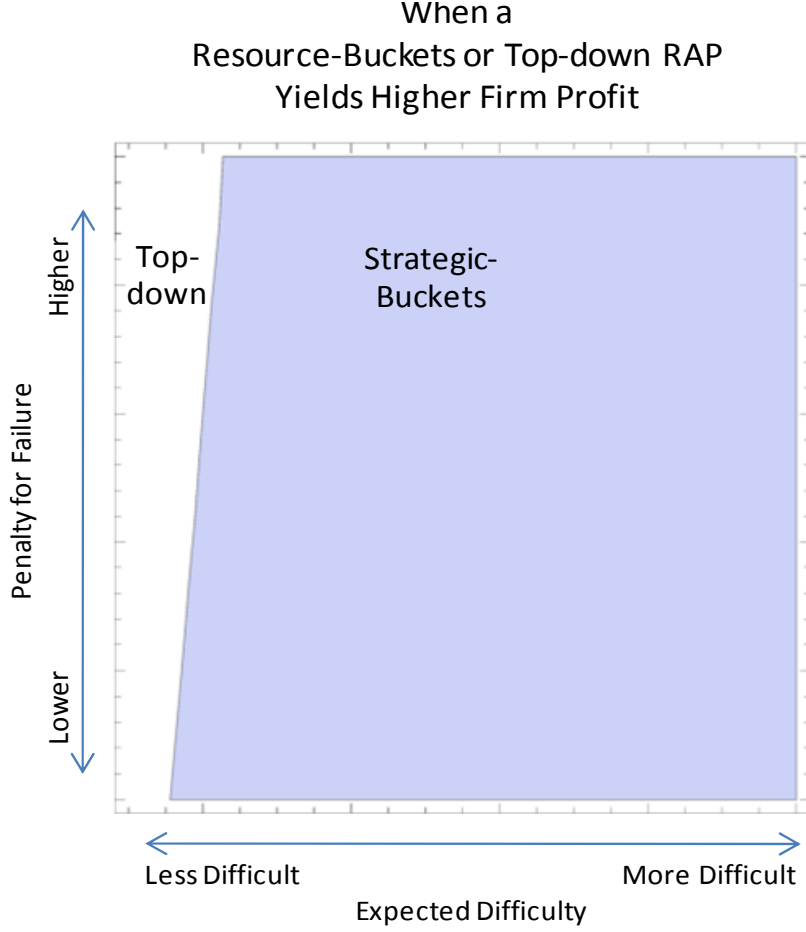


Figure 8: Resource allocation under full-empowerment and top-down resource allocation processes.

- (ii) For sufficiently low $\hat{\Pi}$, the feasible set of initiatives under a strategic buckets process is larger than under a top-down process.
- (iii) A strategic buckets process weakly dominates a full-empowerment process for all $E[\theta]$ ¹⁹.

As we did in Proposition 9, in Proposition 13 we characterize the difference between delegating resource allocation via a strategic buckets process, and dictating

¹⁹ When the set of potential difficulty levels for the initiative contains more than two elements, then a strategic buckets RAP may not be dominant for all expected difficulty levels. In the Appendix we offer such an example for three potential difficulty levels.

resources via a top-down process, and we contrast the strategic buckets RAP with the full-empowerment one. Again, we find that for initiatives with a higher potential difficulty, the use of delegation (i.e. the choice of between available buckets) to capitalize on the knowledge of the PM becomes more beneficial. However, strategic buckets make use of a very powerful aspect of delegation: they “ earmark ” the resources for initiatives that may otherwise seem too far-fetched to receive *any* funding. Thus, although it may be hard to dictate these initiatives, a strategic buckets RAP ensures enough funding for such long-shot projects. Therefore, the firm can profitably go after initiatives that may be more difficult (i.e. more “ radical ”), in the sense that they are not well grounded in the firm’s competencies and may represent more difficulty to the firm.

Proposition 13 (iii) eludes to the power of using a strategic buckets RAP. Such a process dominates a full-empowerment one for the following reason: both the full-empowerment and the strategic buckets processes utilize a common compensation scheme, albeit full-empowerment employs profit sharing, while a strategic buckets process uses a fixed wage. The inefficiency of the full-empowerment process arises because the common compensation is the only lever the VP has, i.e. the PM controls the resource allocation, resulting in over-investment for initiatives with lower expected difficulty. Yet, when the VP categorizes the resource allocation, and an appropriately set wage, she can replicate any solution obtained through full-empowerment given the control she has over the resource levels of the strategic buckets. However, it is worthwhile to point out that, this result does not always hold when the project types are defined with more granularity. In such cases, the lack of a clear cut dominance stems from the fact that the VP needs to offer a premium to induce the proper sorting of the initiatives into their respective buckets, and this premium may be too great to allow the VP to sort the initiatives into all of the different buckets, i.e. even though there are n type of difficulty for the initiative, the VP may only be able to segment

the initiatives into $n' < n$ buckets. In the end, the loss from the premium and the added need to sort the initiatives may result in a greater loss under the strategic buckets RAP than the loss incurred through delegation. Thus, it may happen that it is less costly to allow the PM to fully define the resources for the initiative on his own, as opposed to inducing him to adopt a pre-defined funding option up front, i.e. strategic buckets.

3.5 *Discussion and Conclusions*

In this paper we set out to explore a fundamental question regarding resource allocation: what resource allocation process should a firm use when undertaking a NPD initiative? Since Bower's (1970) early work regarding the resource allocation processes in organizations, scholars have observed in numerous field studies the presence of different approaches. Surprisingly enough, few studies have looked at when and how such different processes should (and could) be implemented. Our study aims to address this gap. We consider a problem setting where the senior management of a firm aims to implement a key strategic NPD initiative. As articulated in the prior literature, certain organizations allocate resources in a *top-down* fashion, i.e. resource decisions are made at senior levels within the organization; while others follow a *bottom-up* resource allocation process, where initiatives are outlined at senior levels but the resource decisions are made by middle-management (project managers). At the time funding decisions are made, rarely does senior management understand the tasks required to execute the initiative as well as the project manager himself. This difference between the stakeholders' knowledge of the initiative (information asymmetry), prompts a distinct agency setting that results from the fact that the stakeholders face different consequences should the initiative fail (i.e. the firm incurs the full cost of resources, and the PM suffers career setbacks). To address the

inefficiencies associated with this agency setting, the VP faces a choice between empowerment and control. Control is maintained by dictating a fixed resource budget to the PM, with the objective to efficiently allocate resources. Unfortunately such efficiency comes at a cost; the VP rarely knows the exact difficulty of the initiative and she needs to decide on budgets given this uncertainty. In contrast, empowerment delegates the resource allocation decision to the PM, and represents the VP’s effort to capitalize on the effective use of the PM’s specialized knowledge about executing the initiative. Yet, delegation comes with its own cost as well, it requires substantial incentive compensation in an effort to align the objectives of both stakeholders.

Our model analysis provides an operational perspective in support of Burgelman’s (1983) early observation that no single project definition process (i.e. top-down or bottom-up) is appropriate for all firms and all initiatives. We are able to identify under what conditions each process applies. That is, firms should apply resource allocation processes that maintain control, when their objective is to fund relatively well known domains (initiatives with low expected difficulty), while delegating the resource allocation decision is more beneficial when the domain is less known (initiatives with high expected difficulty). Yet, our most intriguing insight stems from the pursuit of an optimal resource allocation process. In order to define such a process we need to depart from the use of a single, common rule for compensation, i.e. a common fixed wage or a common profit-sharing incentive. Admittedly, this adds complexity in the implementation of such a process (Mihm 2010) and raises potential issues of fairness (Fehr et al. 2007). Nonetheless, we characterize such a process as it lends insight for feasible firm practices that could further improve resource allocation when the associated implementation costs are not severe. More importantly though, it gives rise to a related “next-best” process that has found much use in practice: resource allocation via strategic buckets. Our results elaborate on the implications of the resource allocation process on the firm’s ability to adapt its portfolio, and

how such an ability is strongly dependent on the resource allocation process and the structural context (incentives, decision rights and culture) of the firm.

Each firm's choice of a RAP depends on the strategic objectives, the organizational norms that define the PM's consequences for failed initiatives, and how well senior management understands the detailed tasks required to execute the initiative. We find that for those firms wishing to fund relatively well known domains (standard tasks), the benefits they incur by tailoring resource allocation levels to the task difficulty are outweighed by the efficiency gained when senior management dictates the resource allocation. However, when the information asymmetry is high, this may no longer be the case. In such instances, of high asymmetry, the VP benefits from offering incentives that align the PM's interests with the overall firm objectives. When this is the case, the gains realized from aligning the stakeholder objectives outweigh the cost of incentives and the firm reaps benefits from effectively tailoring resource allocations. There is a caveat, a firm with low tolerance for failure (i.e. a harsh penalty for failure) may preclude the firm from achieving alignment on such high difficulty initiatives. In a harsh environment, it may never be beneficial to delegate; the need to offset the failure consequences makes it too costly to provide incentives that align the utility of the PM with the objectives of the firm (utility of the VP).

Additionally, our research offers an alternative justification for the use of strategic buckets, which is often observed in practice. Strategic buckets are widely cited as a means to ensure that funds are earmarked for difficult (i.e. radical) initiatives. Generally, they are advocated based on forward looking statements (Chao and Kavadias 2008), or statements based on fear of mismanagement (Terwiesch and Ulrich 2008). The logic is as follows: firms know they need to conduct radical (difficult) projects; yet if they do not protect funds for radical projects for long enough periods of time, or if those funds are not explicitly labeled for such difficult initiatives, then the funds will get used elsewhere, i.e. on more incremental and short-term initiatives. Armed with

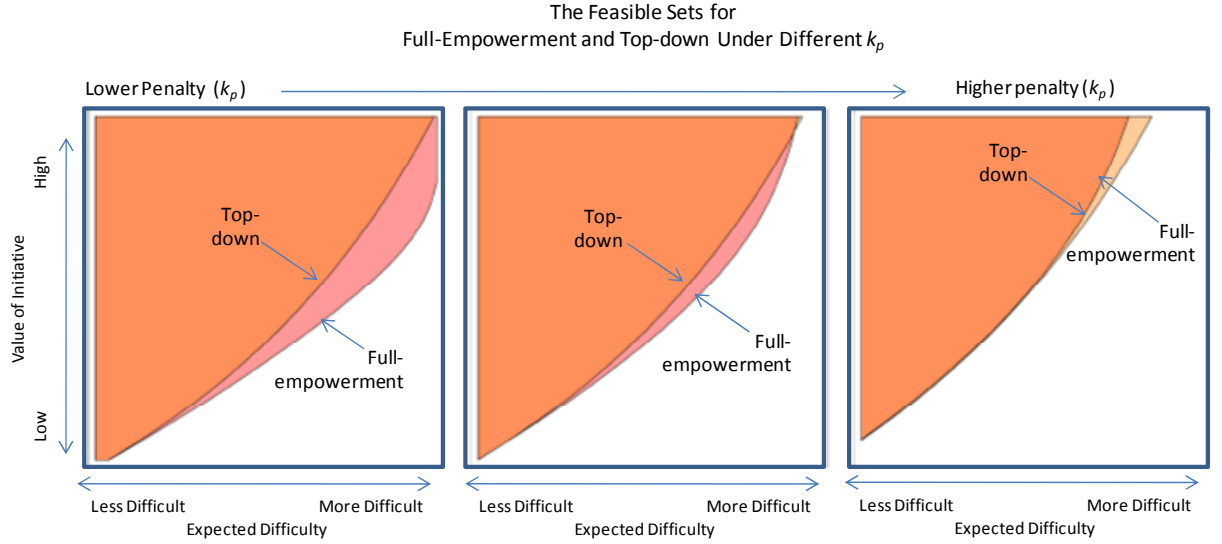


Figure 9: Resource allocation under full-empowerment and top-down resource allocation processes. The left panel represents a lower penalty for failure and each panel to the right represents the feasible sets with increasing penalties, where eventually as shown in the right panel, the top-down feasible set is dominant as compared with the full-empowerment one.

such a capability the firm can address the issue of what portion of projects should be more radical or incremental. Our explanation for strategic buckets is somewhat different: senior managers of NPD organizations are unsure of the exact difficulty of the strategic initiative they aim to implement. In an effort to ensure that resources are properly tailored to execute the appropriate difficulty initiative, such that the firm does not only pursue incremental initiatives under the premise of more difficult ones, senior management can use strategic buckets to segment the projects, and thus more effectively fund them. In addition, this result highlights a positive side effect of having at least *some* penalty for failure. Such organizational norms allow implicit means by which the firm can manage the PM's utility, and influence his decisions, without implementing complex compensation, i.e. incentive feasible Bayesian mechanisms, with non-linear, project type dependent compensation.

Finally, an important implication of the choice of the “right” resource allocation

process, i.e. a RAP contingent on the context within which initiatives are executed, is the firm's ability to adapt its portfolio to a given strategy. Our results on the feasible set of initiatives show that the choice of resource allocation process given the organizational norms, dictates whether an initiative, and as such, part of the firm's strategy, can be executed. The feasible set of initiatives represents bounds on the initiatives the firm can execute, and it is an analog to Markowitz's (1952) notion of an attainable set of investments that an individual investor can include in their portfolio given a particular set of risk preferences. Thus, given a particular resource allocation process, there is a feasible set of initiatives that the firm can fund (i.e. the maximum expected difficulty the firm can undertake for a given potential value). Although the organizational norms impact the feasible set in a unidirectional manner (i.e. regardless of the process, a higher penalty implies a smaller feasible set), the impact is more severe when the resource allocation process is one of empowerment. A graphical representation of this is shown in Figure 9.

In conclusion, our work places emphasis on the need for senior management to consider operational details of NPD initiatives when determining the firm's resource allocation process. As a first step towards this direction, we bear limitations that open potential avenues for future research. Future work needs to shed additional light on the delegation of strategy definition (which initiatives to pursue) and account for effects of competition. Furthermore, future work should also establish how certain organizational norms, i.e. the penalty for failure, come to fruition, thus adding detail to such a temporal process (Chassang 2010). Finally the effects of the collaborative and cross-functional nature of innovation should come under scrutiny.

CHAPTER IV

TOLERANCE FOR FAILURE AND INCENTIVES FOR INNOVATION

4.1 *Introduction*

Most innovation or new product development (NPD) initiatives are managed in collaborative innovation teams (Roussel et al. 1991, Wheelwright and Clark 1996, Loch and Terwiesch 2009)¹. Collaborative innovation teams require different functional or technical managers, such as marketing, operations, engineering, and R&D among others, to allocate resources to a project (Sosa and Mihm 2008). Those resources are deployed to execute project tasks, such as design, concept generation, prototyping, and testing (Ulrich and Eppinger 2004), which are geared toward reducing technical and market risk in order to ensure viable development.

While the use of collaborative innovation teams is a good way to spark innovation, an organization can also influence the risk-taking behavior of the managers that allocate resources to collaborative innovation projects. This is often accomplished through monetary incentive schemes (e.g. performance based rewards and bonuses) and/or through an organizational culture that tolerates failure (e.g. not penalizing employees involved in failed innovation initiatives)². However, blindly handing out

¹The definition of “collaborative” will differ depending on the context and academic heritage of the reader. Webster defines collaborative as, “produced or conducted by two or more parties working together”. For our purposes, collaboration can be defined as shared control over critical project decisions. One of the most well-known collaborative innovation initiatives was the development of the Airbus A380. This project consisted of over 5,000 engineers and development personnel from 12 different functional areas and divisions (Sosa and Mihm 2008).

²An example of incentives for innovation exists at Google, where members of the Chrome web browser development team were rewarded bonuses that totaled millions of dollars upon successful development (Eustace 2009). Likewise, companies such as IDEO exhibit tolerance for failure when they encourage employees to, “fail often to succeed sooner” in order to spark innovation (Thomke 2001).

rewards or ignoring failures may not be appropriate in all settings. It is therefore important to understand how incentives and tolerance for failure work in concert with one another to influence managerial decision-making in new product development.

In this paper we conduct a controlled laboratory experiment to study how rewards and penalties impact the decisions of project managers engaged in a collaborative innovation initiative. While a number of studies have explored the isolated effects of rewards (Holt and Laury 2002, 2005) or penalties (Bolton and Zwick 1995) in the general context of decision-making under risk, the combined effect of these levers remains relatively unexplored. The few studies that do consider both rewards and penalties do so in a setting where the probabilities associated with mixed gambles are fixed (Birnbaum and Bahra 2007, Wu and Markle 2008) or the risk is faced by one individual (Manso 2011, Ederer and Manso 2010). To our knowledge, our work is the first to empirically explore the combined influence of rewards and penalties on a collaborative innovation initiative. Furthermore, the majority of existing studies do not consider risk that can be altered by the actions of the decision-maker, as is the case in NPD projects.

NPD projects are defined by risk that can be reduced by the resources assigned to a project, a feature we call endogenous project risk. This feature stands in contrast with the (exogenous) risk faced by the typical financial investor or gambler that is often cited in studies of decision-making under risk (Sutter 2007). In addition, NPD projects often require input from and collaboration between multiple functional managers. We define collaboration in terms of shared control over critical project decisions, such as the amount of resources to invest in a project. These two facets of NPD - endogenous project risk and collaboration between multiple functions - make NPD a particularly novel setting for the study of incentives and tolerance for failure. While endogenous project risk is often modeled theoretically (Laffont and Martimort 2002, Aghion and Tirole 1994), we believe our work is the first to provide an empirical

understanding of decisions made under endogenous project risk.

Our study provides three results, one of which is intuitive while the other two appear to be novel contributions to the literature. First, subjects choose to allocate more resources when the reward is high or when the penalty is low. While this result is intuitive, it does serve a purpose in that it shows that rewards and penalties behave as expected when managers face endogenous project risk. Since most empirical studies on rewards and penalties are carried out in settings where the decision maker cannot directly influence the risk he/she faces, it seems important to confirm intuition in a setting characterized by endogenous project risk.

Second, we find that the way in which project control is administered moderates the effects of both rewards and penalties. When control over critical project decisions is shared, subjects do not internalize the effects of reward or penalty as much as they do when control rests with one individual. The implication is that managerial rewards do not positively influence actions as much (and penalties do not negatively influence actions as much) when the control of a project is shared between multiple functional (or technical) managers. Effects associated with free riding (Kim and Walker 1984, Siemsen et al. 2007) are often cited to explain that individuals invest at a lower level when control is shared. The nature of our result is such that, in some cases, individuals may actually invest at a higher level in a setting characterized by shared control and either low rewards or high penalties.

Our third result highlights when and how subjects alter their appetite for risk depending on project characteristics and the rewards/penalties offered by the firm. When rewards and penalties are balanced so that both are high or both are low, subjects tend to exhibit a greater risk appetite. Conversely, when rewards and penalties are not balanced, subjects tend to scale back their risk appetite. This result is particularly interesting because shifting risk appetite may have unintended consequences if it leads managers to misalign themselves with corporate strategy (regardless of

whether that strategy calls for more or less risk appetite).

Taken together, these insights have important implications for senior executives charged with delivering innovation and creating growth. A common refrain among these executives is the need to manage resource allocation and risk taking on the part of their employees. While our first instinct is to assume that firms should always encourage risk taking (perhaps because of the potential value associated with risky innovation initiatives), it is important to remember that there are many instances in which the firm would do well to encourage less risk appetite (as is often the case with process improvement programs). A simple anecdote from practice highlights this point. One senior executive at a large multinational service company stated that, “It is important that our project managers align their risk appetite with our need to grow the business in key markets. Too often we find that project risk is cited as a reason for not engaging in what was thought to be a promising project. It leaves us wondering if perhaps we are penalizing them too much, focusing them on the short term, and not rewarding them for taking appropriate risks” (Sevillano 2011).

4.2 Related Literature and Theory Development

Our study is related to the literature on rewards, penalties, and control in organizations. As we shall see below, researchers in economics, psychology, organization theory, and new product development have contributed to these themes in different ways. These contributions tend to be focused on either economic (Holmstrom 1979, Eisenhardt 1989) or psychological (Miner 2005) mechanisms.

4.2.1 The Positive Effect of Rewards

Studies that highlight a positive influence of rewards are often based on agency theory - the premise that economic agents and their principals have diverging interests and it is costly or impossible to perfectly monitor the actions of the agent (Laffont and Mortimort 2002). The principal should therefore provide a reward (incentive)

to encourage the agent to take action that is positively aligned with the principal's objective (Gibbons 1998, 2005, Kaplan and Henderson 2005). There are a number of theoretical agency models that highlight how rewards and incentives positively influence behavior (Holmstrom 1979, Pendergrast 1999, Lazear 2000, Manso 2010). In addition, there is a significant body of work aimed at empirically verifying the positive influence of rewards predicated by agency theory (Lazear 1996, Ichniowski Shaw and Prenzushi 1997, Lazear 2000). In R&D and product development settings, the positive effect of rewards has been highlighted in the context of hierarchical planning (Anderson and Joglekar 2005) and strategy implementation (Loch and Tapper 2001), among others.

Psychologists have also studied the positive influence of rewards, albeit from a broader perspective related to motivation (Miner 2005). One aspect of motivation deals with expectancy, or the belief that rewards increase the strength (valence) of the cause and effect relationship between desired actions and outcomes (Vroom 1964, Porter and Lawler 1968). Similarly, rewards can act as a positive reinforcement mechanism when the desired performance is clearly stated and rewards are contingent on that performance (Skinner 1953, Hamner 1974, 2005). The positive effect of rewards can also be credited to an individual's need for achievement (McClelland, Atkinson, Clark and Lowell 1953, Bonner and Sprinkle 2002). Achievement theories are based on the fact that individuals strive to be perceived as high ability, and a reward that can be attributed to success reaffirms that perception since, "success is ascribed to high ability and hard work, and failure is attributed to low ability" (Weiner 1992, p. 549). Considered together, this work suggests that rewards have a positive effect on effort.

4.2.2 The Negative Effect of Penalties

Rewards only represent one side of the coin when it comes to using incentives to influence behavior. An alternative is to use a penalty or punishment as negative reinforcement. Psychologists have reasoned that penalties have a negative influence on behavior because of loss aversion (Kahneman and Tversky 1979, Tversky and Kahneman 1981). In new product development settings, loss aversion may magnify the implicit costs or penalties incurred by managers. For example, Chao et al. (2009) show how a higher implicit cost paid by a manager that runs over budget leads the manager to invest less in NPD projects. Similarly, Mihm (2010) shows that higher penalty paid by engineers that design components with cost overruns lead to less effort on the part of those engineers. These papers and others like them (Hutchison-Krupat and Kavadias 2010) all focus on the negative effect of penalties (“the stick”) as opposed to the positive effect of rewards (“the carrot”).

Beyond the choice of “the carrot or the stick” as a means of positive or negative reinforcement (Dickinson 2001, Andreoni Harbaugh and Vesturlund 2003), there is a related stream of literature that cites a firm’s tolerance for failure (or lack thereof) as another lever that affects employee actions. Low tolerance for failure has been shown to decrease investment in innovative activities in both theoretical models (Manso 2011) and in empirical settings (Ederer and Manso 2010, Tian and Wang 2009). Together, this stream of literature suggests that penalties have a negative effect on effort.

4.2.3 The Effect of Shared Control

For our purposes, control is a function of whether a manager maintains individual responsibility and accountability for a project as opposed to sharing the responsibility and accountability with another manager. While the direct effects of rewards and penalties are relatively straight forward, the effect of shared control is less so.

In particular, it is not immediately obvious how control influences the relationship between rewards/penalties and effort. Studies that cite a negative moderating effect of shared control tend to focus on free-riding (Kim and Walker 1984, Siemsen et al. 2007) as the mechanism that dampens the effects of rewards or penalties. In our context, free-riding occurs if an individual in a shared control setting invests less than a “fair share” of resources (Kim and Walker 1984). One reason that free-riding may occur in a shared control setting is that uncertainty regarding the actions of other players involved in a strategic interaction leads each player to invest at a lower level (Holmstrom 1982).

On the other hand, a number of studies cite a positive moderating effect of shared control due to the diffusion of responsibility/accountability (Clark 1974) or perceptions of “risk-as-value” (Clark, Crockett, and Archer 1971, Hsee and Weber 1997). The former can be interpreted as a form of risk pooling that takes place when multiple individuals share control or engage in an activity together, while the latter is based on the fact that society (and by extension social entities such as teams) value risk-taking over cautious behavior. Siemsen (2008) provides an example of such behavior in the context of NPD as it relates to design engineers purposefully undertaking difficult (risky) projects so they can signal their skill. Based on the conflicting arguments supported by free-riding, diffusion of responsibility, and risk-as-value, we do not offer an a-priori hypothesis regarding the moderating role of shared control.

4.3 Experimental Design and Procedure

We designed and implemented a controlled laboratory experiment to study the arguments set forth above. In what follows we present a simple model that serves as the foundation of our experiment. We then go on to describe the decision, treatments, and other procedural details related to the experiment.

4.3.1 A Model of Endogenous Project Risk with Reward and Penalty

One of the distinguishing characteristics of innovation and new product development is the considerable risk that managers face during project execution. This risk can be reduced (albeit not entirely) when a manager allocates resources to a project. We refer to this aspect of NPD projects as endogenous project risk. While there is a substantial volume of literature that evaluates risky allocation decisions (Levy 1994, Gneezy and Potters 1997, Sutter 2007, Charness and Gneezy 2010), the majority of these studies consider the risk associated with the investment as independent (exogenous) of the investment itself. While this makes sense in circumstances such as the individual investor or a gambler, this may not make sense when evaluating the firm's internal operations, as is the case when assigning resources to a NPD project. In most NPD projects, the manager (or managers) who oversee the project, and who are subject to receiving a reward or a penalty based on the outcome, can manage the exposure they have to risk.

Consider a setting in which a single manager has control over the resources allocated to a project. Let $p(r) = r/(\theta + r)$ be the probability that the project is successful given a resource allocation of r ³. The parameter θ is project specific and captures risk that is present regardless of the resources allocated to the project. If the project is successful, it delivers a value v to the firm and if it fails it delivers no value to the firm. One can think of v as the discounted revenue stream generated by the project upon successful development. Two things are important to note here. First, the probability of success for the project is increasing in the resources allocated to the project. This captures the endogenous project risk that is characteristic of product development. Second, for a given level of resource investment, projects with higher

³We consider "resource allocation" to be a proxy for the many disparate activities that serve to reduce risk (increase the likelihood of success) for a project. These may include things such as resources dedicated to understanding customer needs (Griffin and Hauser 1993) or the number of prototyping tests to run (Terwiesch and Loch 2004), among others.

θ have lower probability of success compared to projects with lower θ . We therefore interpret θ to be a proxy for the implicit project risk (i.e. so-called “incremental” or “radical” initiatives). A project manager with individual control over the project must decide how many resources to allocate to the project given that he receives payoff

$$V = \begin{cases} \alpha(v - r) & \text{if the project is successful} \\ -\beta r & \text{if the project fails} \end{cases}$$

where α is the incentive parameter that characterizes the level of reward given to the manager if the project is a success and β is the tolerance for failure parameter that characterizes the level of penalty imposed on the manager if the project is a failure. The reward is proportional to the project’s profit and the penalty is proportional to the resources consumed by a failed project.

In a collaborative innovation initiative with shared control, each manager must account for his resource allocation decision as well as that of his counterpart. Suppose there are two managers that share control over the project, each with payoff

$$V_i = \begin{cases} \alpha(v - r_i - r_j) & \text{if the project is successful} \\ -\beta(r_i + r_j) & \text{if the project fails} \end{cases}$$

where r_i is the resource allocation decision of manager i and r_j is the resource allocation decision of manager j . In the case of shared control, the probability that the project is successful depends on the resource allocation decisions of both managers. Therefore, we have $p(r_i, r_j) = (r_i + r_j)/(\theta + r_i + r_j)$ in the case of shared control.

4.3.2 The Decision

Subjects were asked to decide the level of resources to invest in each of 8 projects that were presented in sequence. We randomized the order in which we presented the projects in order to avoid framing or ordering effects. In accordance with the model described above, subjects were told that their investment would alter the probability

of success for the project. For each subject, each of the 8 projects was presented in a table that included i) the option to invest between 0 and 25 resources to the project, ii) probability of project success based on the investment decision, iii) reward if the project is successful, iv) probability of project failure, and v) penalty imposed if the project fails. In the Appendix we provide the exact instructions presented to subjects along with a sample question.

4.3.3 Experimental Design and Treatments

Our experimental design consists of treatments for i) reward, ii) penalty, iii) project risk, and iv) project control. We implemented each treatment at two levels leading to a $2 \times 2 \times 2 \times 2$ factorial design. Furthermore, we varied three of the treatments (reward, penalty, and project risk) within subject and one of the treatments (project control) between subjects. We did this for two reasons. First, this experimental design allows us to limit the number of questions asked of each subject to only 8. Second, we believe that subjects can focus more clearly on each question if they are not asked to switch between a setting where they are the sole decision maker and one where they are one of two decision makers for the project. This also allows us to frame all of the qualification questions in a single context and test that they understand that context. Both of these experimental design decisions limit the cognitive burden placed on each subject during our experiment. Figure 10 presents a summary of our treatments and experimental conditions. Below, we describe each treatment in greater detail.

4.3.4 Project Control

The treatment for project control was implemented between subjects by randomly assigning subjects to one of two groups: individual control or shared control. In the individual control group, subjects were told that their decision alone would determine the probability of success for the project, and therefore, their potential reward or penalty. In the shared control group, subjects were told that the probability of

Variable	Treatment	Implemented	Description
Project Control	Individual: r Shared: $r_1 + r_2$	Between Subjects	Resource allocation alone or combined with another subject.
Project Risk	Low: $\theta = 15$ High: $\theta = 90$	Within Subject	Low risk projects first-order stochastically dominate high risk projects.
Reward	Low: $\alpha = 0.1$ High: $\alpha = 1.0$	Within Subject	% of project profit earned by subject if project is successful.
Penalty	Low: $\beta = 0.1$ High: $\beta = 1.0$	Within Subject	% of project costs paid by subject if project fails.

Figure 10: Experimental Design.

success was determined by the resources that they assigned as well as those resources assigned by another player. They were told that ultimately the total number of resources assigned by both players would determine the potential reward or penalty they would receive, and the probability of each respective outcome.

We informed subjects in the shared control group that the other player was given the exact same information as they were. This creates common knowledge and avoids any superfluous asymmetries between subjects. For the shared control group we also scaled the resource allocation options offered to the subjects by a factor of two. This ensures that the amount of reward or penalty received by the subjects is equivalent under individual and shared control. We can therefore easily compare the decisions that a subject makes under individual control with the same decision that a subject makes under shared control.

4.3.5 Project Risk

The treatment for project risk was implemented at two levels within subject by altering the relationship between the resources allocated to the project and the probability of success. The functional form the used for the probability of success is $p(r) = r/(\theta + r)$. As before, θ is a scaling parameter that characterizes how risky the project is (higher θ representing a higher risk project) and r represents the resources allocated to the project (either individually or shared). The low risk treatment is characterized by $\theta = 15$ and the high risk treatment uses $\theta = 90$.

Figure 11 depicts a low-risk project and a high-risk project for a typical question. As is evident from the figure, to achieve a given probability of success, the subject would have to allocate more resources in a high-risk project. Similarly, for a given level of resource allocation, the probability of success for a low-risk project is always higher (this condition implies that low risk projects first-order stochastically dominate high risk projects). Furthermore, a high-risk project cannot come close to 100% probability of success for any level of resource allocation while a low risk project comes a lot closer to 100% probability of success with a high enough allocation of resources.

4.3.6 Reward

The treatment for reward was implemented at two levels within subject. We altered the percentage of project profit earned by the subject if the project is successful. For each project, the reward is given by $\alpha(1000 - r)$ where α is the reward percentage and r is the allocated resource (individual or shared). This structure corresponds well with the typical profit sharing or bonus-based incentives used by many firms in practice. Our reward is based on a percentage of project profit because most organizations use performance-based rewards (incentives or bonuses) along this vein. The low reward treatment is $\alpha = 0.1$ and the high reward treatment is $\alpha = 1.0$.

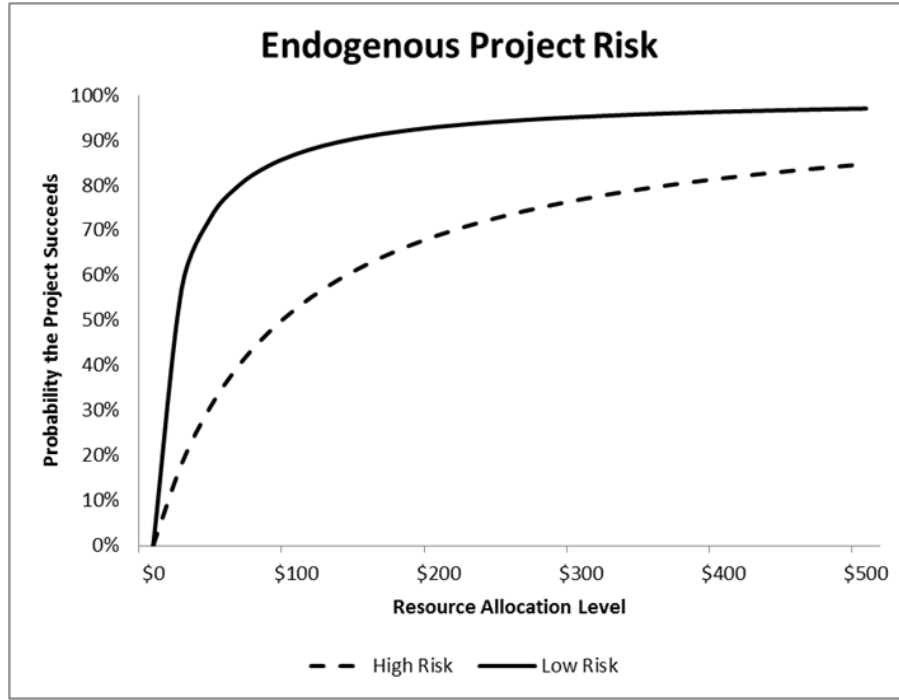


Figure 11: Endogenous Project Risk (Probability of Success Depends on Allocated Resources).

4.3.7 Penalty

The treatment for penalty was implemented at two levels within subject. We altered the percentage of project costs (allocated resources) that the subject would be penalized if the project failed. For each project, the penalty is given by $-\beta r$ where β is the penalty percentage and r is the allocated resource (individual or shared). This structure captures the “tolerance for failure” (or lack therefore) that many practitioners speak of when they try to create a culture of innovation within their firms. We implemented the penalty based on the allocated resources because our research question is geared toward understanding the scale of the project from the perspective

of the firm rather than the individual's cost of effort. The low penalty (high tolerance for failure) treatment is $\beta = 0.1$ and the high penalty (low tolerance for failure) treatment is $\beta = 1.0$.

4.3.8 Qualification and Incentives

We implemented a series of qualification questions and incentives to ensure that subjects fully understand the task at hand and subjects remain engaged throughout the duration of the experiment (the full 8 questions that they are asked to answer).

Qualification questions were aimed at ensuring that subjects understood each dimension of the problem. As such, in each of the treatments for project control (individual and shared) we presented the subjects with a shortened version of the tables they would see for each project. We then asked them specific questions that revealed whether they understood how each variable interacted with the others (sample qualification questions are shown in the Appendix). For the shared control group all questions were phrased to emphasize that there would always be two decision makers affecting the outcome of the project. The shared control treatment required an additional dimension of understanding and is therefore more complex, which is evident from the fact that fewer subjects qualified in the shared control group.

Financial incentives were used to ensure that subjects paid attention throughout the experiment. Each subject was paid a fixed fee for participating in the experiment. In addition, each subject was told that they had the chance to receive a bonus of up to \$200 depending on their performance during the experiment. We followed a standard lottery procedure advocated in the literature to implement the bonus (Camerer 2003). Following the completion of the experiment we randomly selected one of the 8 projects and simulated the results using the choices made by each subject. Based on the results of the simulation, the top five performers (in terms of net gain) were credited 100, 70, 60, 40, and 35 lottery tickets, respectively. All other subjects were each credited 1

lottery ticket. This structure ensures that the top performing subjects have a higher probability of winning the bonus.

4.3.9 Subject Pool

All subjects were U.S. residents selected through the use of Amazon’s Mechanical Turk service. Mechanical Turk has become widespread in experimental and behavioral economics (Paolacci et al. 2010) and it offers a number of advantages over traditional laboratory experiments. First, Mechanical Turk offers access to a heterogeneous population, which more closely resembles the general working population in the U.S. In contrast, most laboratory experiments have homogeneous populations that often consist of undergraduate students. Second, Mechanical Turk may offer stronger internal validity compared to laboratory experiments because anonymity avoids experimenter bias (Orne 1962) and interactions between subjects (Edlund et al. 2009).

Subjects in our experiment were of an average age of 32 with 58% of the subjects having completed an undergraduate degree. Of those that completed an undergraduate degree, over 50% of subjects had more than 4 years of work experience. Overall 38% of subjects passed their respective qualification questions (31% in the shared control group and 46% in the individual control group). The lower percentage in the shared control group reflects the additional dimension of understanding required by subjects in that treatment. Specifically, subjects in the shared control group had to understand the same dimensions as the individual control group (reward, penalty and the relationship between resource allocation and likelihood of success) but they also had to recognize that these dimensions were affected by their decision as well as the decisions made by another subject. After checking for completeness of the responses, our sample has usable data from 152 subjects (85 in the individual control group and 67 in the shared control group), each exposed to 8 projects giving us a total of $N = 1,216$ data points.

4.4 Results

In this section we describe the results of our experiment. We first discuss how rewards and penalties impact resource allocation decisions, then go on to discuss how rewards and penalties influence risk appetite.

4.4.1 How Rewards and Penalties Impact Resource Allocation

To understand how our variables of interest impact resource allocation decisions, we ran three regressions with different specifications (see Figure 12). Specification 1 tests the interactions between reward, penalty, and project type for the “individual control” group only. Specification 2 tests the same interactions for the “shared control” group only. Specification 3 includes the effect of project control in addition to the others listed above. Because our data consist of within and between subject variables, our statistical analysis is performed using a generalized linear model that accounts for repeated measures at the subject level. Each regression uses “resource allocation” as the dependent variable.

	Individual Control 1	Shared Control 2	Combined 3
Parameter	Estimate (std. err.)	Estimate (std. err.)	Estimate (std. err.)
(Intercept)	4.969 (0.463)***	8.507 (0.509)***	4.686 (0.408)***
[Penalty=H]	-3.247 (0.712)***	-1.302 (0.694)*	-1.538 (0.610)**
[Reward=H]	1.718 (0.756)**	1.489 (0.674)**	0.565 (0.584)
[Risk=H]	3.365 (0.706)***	4.608 (0.728)***	4.33 (0.657)***
[Reward=H] * [Penalty=H]	1.047 (0.716)	-0.53 (0.741)	0.352 (0.521)
[Risk=H] * [Penalty=H]	-1.188 (0.873)	-0.455 (0.762)	-0.865 (0.593)
[Risk=H] * [Reward=H]	2.094 (0.676)***	0.366 (0.684)	1.332 (0.488)***
[Control=H] * [Penalty=H]			-1.523 (0.709)**
[Control=H] * [Reward=H]			1.882 (0.683)***
[Control=H] * [Risk=H]			-0.746 (0.745)
Number of subjects	85	67	152
Number of observations	680	536	1216

***p≤0.01, **p≤0.05, *p≤0.10

Figure 12: Regression results with “resource allocation” as the dependent variable.

For the individual control group (Specification 1), the direct effects of reward and penalty are consistent with the discussion in Section 2. High rewards or low penalties lead to higher resource allocation on the part of the manager. In addition, the interaction between the project risk and reward is significant in the individual control group, suggesting that the positive effect of reward is even greater when the project risk is high. For the shared control group (Specification 2), the interaction between project risk and reward is no longer significant. Comparing Specification 1 and 2, it is evident that while the direct effects are directionally consistent, the magnitude of the effect associated with either the reward or penalty is less when control is shared. The same is true regarding the interaction between the project risk and the reward; the effect is directionally consistent, but the magnitude is substantially less (so much so that it is no longer significant in the case of shared control). These results suggest that project control (individual or shared) interacts with reward and/or penalty.

When we include all treatments in one regression (Specification 3) we see that, indeed, there are significant interaction effects between project control, reward, and penalty. When subjects have shared control, the positive relationship between rewards and resource allocation are muted. In fact, when compared to the effect present in the individual control group, rewards do not seem to matter as much under shared control. Similarly, when subjects have shared control, the negative relationship between penalties and resource allocation is significantly mitigated. This moderating effect comes with an intercept change along with a slope change. The interaction effects are depicted graphically in Figure 13.

The results above suggest that when control of the project is shared, subjects do not internalize the effects of reward or penalty as much as they do when the control rests with one individual. This is important because most organizations use cross-functional teams to carry out innovation projects and those teams often exist within some form of shared control (e.g. matrix project organizations). It seems that

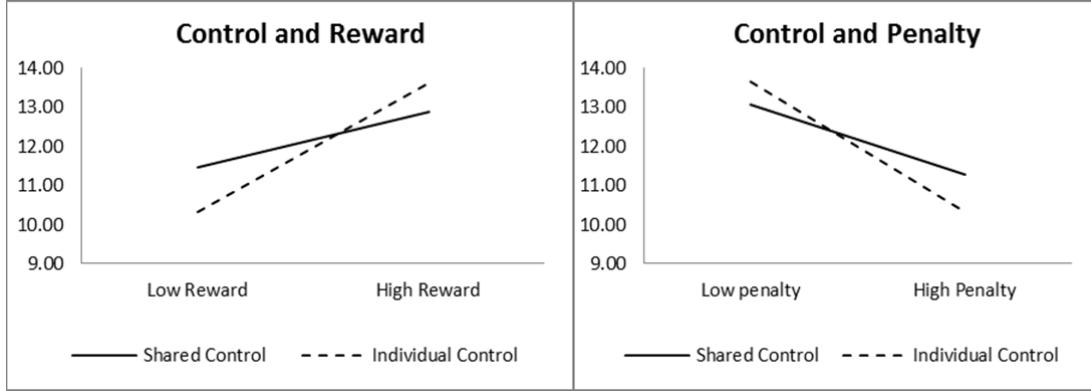


Figure 13: Interaction Effects Between Control, Reward, and Penalty.

shared control leads to a form of free-riding (Holmstrom 1982) only if rewards are high or penalties are low. Conversely, when rewards are low or penalties are high, shared control actually drives higher resource allocation. This suggests that diffusion of responsibility or risk-as-value dominates when rewards are low or penalties are high in a shared control setting.

One final thing to note from our regressions is that project risk is significant for all regression specifications. Subjects choose to invest at a higher when the project risk is high. This result seems odd at first glance because one would expect a risk-averse manager to invest at a lower level when facing higher risk. However, because our setting is characterized by endogenous project risk, subjects can actually lower the risk they face by investing more resources. This suggests that there is an “acceptable” level of risk that the manager is willing to take on for each project and for each organization (i.e. for each combination of reward and penalty). Understanding the manager’s appetite for risk is the focus of the section that follows.

4.4.2 How Rewards and Penalties Impact Risk Appetite

Motivated by the discussion above, we now turn our attention to exploring how rewards and penalties influence risk appetite, which requires us to specify a model of

decision-making under risk. The two most well studied theories related to decision-making under risk are expected utility theory (Morgenstern and Von Neumann 1947) and prospect theory (Khaneman and Tversky 1979, Tversky and Khaneman 1992). Figure 14 presents the coefficient of risk aversion and the resulting error achieved when we fit our experimental data to each of four popular utility forms advocated in the literature. For each utility form, we fit the coefficient of risk aversion by minimizing the error between predicted allocation and observed allocation for each of the 16 treatment combinations in our study⁴.

Utility Model	Form for $U(V)$	Risk Properties	Fitted Coefficient of Risk Aversion	Relative Error ^a
Power	V^a	Decreasing Absolute, Constant Relative	$a = 0.703$	21%
Exponential	$1 - \exp(-aV)$	Constant Absolute, Decreasing Relative	$a = 0.002$	18%
Expo-Power	$\frac{1 - \exp(-\omega V^a)}{\omega}$	Constant Absolute, Increasing Relative	$a = 0.506$	49%
Prospect Theory ^b	V^a if $V > 0$, $(-V)^a$ if $V < 0$	N/A	$a = 0.560$	29%

^a Relative Error = $\sqrt{\sum_i (r_i - \bar{r}_i)^2 / \sum_i r_i^2}$ where r_i is the predicted allocation for each treatment under the respective utility model and \bar{r}_i is the mean observed allocation for each of the 16 treatment combinations.

^b We provide only the value functions associated with gains and losses for prospect theory. The utility in prospect theory is linear combination of these value functions that uses positive and negative weighting functions and a loss aversion parameter. Note that we constrained the parameters over gains and losses to be equal. We do this to maintain the same degrees of freedom between each utility model, and point out that Tversky and Kahneman (1992) empirically find these two values to be the same.

Figure 14: Fitted Coefficient of Risk Aversion and Relative Error.

Based on the results presented in Figure 14, we choose a power utility as the form to study the effects of rewards and penalties on risk appetite. We used the power utility for two reasons. First, the power utility is the most common form used in the

⁴Most of the models presented in Figure 14 have additional parameters beyond the coefficient of risk aversion. In these cases, we fix those additional parameters at values most commonly advocated in the literature. As a robustness test, we also fit these utility models with all parameters free. This exercise often resulted in parameter values well outside the accepted range reported in prior studies.

literature of decision-making under risk (Smith 1995, Smith and Nau 1995). Second, although the exponential utility performs marginally better in terms of error, the power utility function performs sufficiently well and is more parsimonious. Using a power utility (and assuming that each subject made utility maximizing decisions) we can calculate the coefficient of risk aversion that is implied by the choices our subjects made. Thus, we can transform our current dependent variable (resources allocated) into a new dependent variable (coefficient of risk aversion)⁵. In the Appendix, we provide a detailed explanation of this procedure along with a sample calculation.

With our new dependent variable we can learn how project control and project risk interact with the various combinations of reward and penalty to determine the coefficient of risk aversion (i.e. risk appetite) that each subject adopts for different project settings. Figure 15 shows the results when we use “coefficient of risk aversion” as the dependent variable. As before, specification 1 tests the interactions between reward, penalty, and project risk for the “individual control” group only. Specification 2 tests the same interactions for the “shared control” group only. Specification 3 includes the effect of project control in addition to the others listed above.

In all specifications, penalty has a significant negative effect on the coefficient of risk aversion, suggesting that penalties make subjects more risk averse. This effect comes about because subjects want to avoid the negative payoff associated with penalties when the project fails. Rewards also have a negative effect on the coefficient of risk aversion, albeit only significant in the case of individual control. This suggests that subjects want to ensure that the project succeeds in order to receive the reward, particularly when they make decisions alone. Taken together, these results suggest that endogenous project risk may create a situation in which subjects curb their risk appetite when either rewards or penalties are higher.

⁵This is essentially the same procedure followed by most classic studies of decision-making under risk. Since risk aversion is a latent parameter that cannot be measured directly, it must be inferred from choices made between lotteries of varying risk.

	Individual Control	Shared Control	Combined
	1	2	3
Parameter	Estimate (std. err.)	Estimate (std. err.)	Estimate (std. err.)
Intercept	2.225 (0.099)***	1.419 (0.124)***	2.289 (0.112)***
[Penalty=H]	-0.562 (0.176)***	-0.769 (0.235)***	-0.737 (0.186)***
[Reward=H]	-0.573 (0.209)***	-0.235 (0.215)	-0.194 (0.182)
[Risk=H]	0.418 (0.322)	-0.135 (0.204)	0.115 (0.221)
[Reward=H] * [Penalty=H]	1.188 (0.269)***	0.872 (0.304)***	1.048 (0.202)***
[Risk=H] * [Penalty=H]	-0.345 (0.285)	0.086 (0.205)	-0.155 (0.184)
[Risk=H] * [Reward=H]	-0.283 (0.258)	0.18 (0.199)	-0.079 (0.170)
[Control=H] * [Penalty=H]			0.149 (0.214)
[Control=H] * [Reward=H]			-0.412 (0.216)*
[Control=H] * [Risk=H]			0.106 (0.222)
Number of subjects	85	67	152
Number of observations	680	536	1216
***p≤0.01, **p≤0.05, *p≤0.10			

Figure 15: Regression results with “coefficient of risk aversion” as the dependent variable.

A particularly interesting insight from our regression analysis is the significant interaction between reward and penalty in all regression specifications. Figure 16, depicts this interaction for the combined sample, and it highlights the importance of balance between rewards and penalties. Balance between reward and penalty occurs in situations in which rewards and penalties are both high (or conversely rewards and penalties are both low). When rewards and penalties are balanced, managers are willing to assume more risk. When rewards and penalties are imbalanced, managers become more risk averse.

The result above is particularly interesting because it brings to light the levers that must be used if the firm wants to drive higher or lower risk appetite. Since there are situations in which either of these may be desirable, it makes sense to set rewards and penalties in a manner that is aligned with the firm’s strategy. For example, if the firm’s strategy is to enter a new (unknown) product market, it would do well

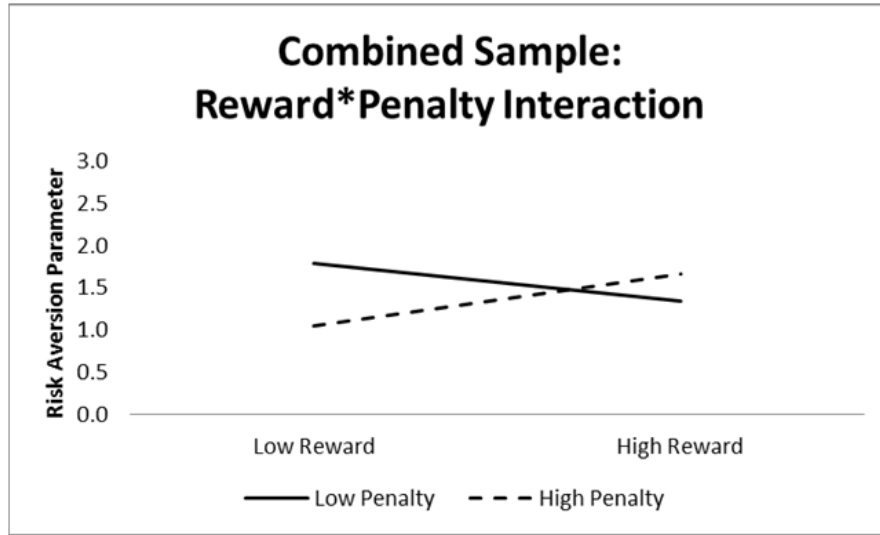


Figure 16: How the balance between reward and penalty impact risk appetite.

to balance rewards and penalties so that managers align their risk appetite with the risk that is sure to come in a new market. Conversely, if the firm's strategy is to successfully implement a process improvement initiative, it might make more sense to purposefully imbalance rewards and penalties so that managers lower their risk appetite.

4.5 Discussion and Conclusion

We conducted a controlled laboratory experiment to evaluate the effects of (positive and negative) incentives on managerial decision making within the context of new product development. An important aspect that differentiates our study from others (and aligns it with the practice of new product development) is the manner in which resources are critically linked to the probability of success. Rather than decouple the probability of success from resource allocation (as is often done in experiments associated with decision-making under risk), our experiment links resource allocation directly to likelihood of success.

Recently, scholars have taken note that some effects studied in behavioral experiments may be lost (or caused) by the practice of “decoupling” specific factors within an experiment. An example is the recent work of Wu and Markle (2008) that objects to some claims of prospect theory based on the separability of gains and losses. Along the same lines, we question the separability between the likelihood of success of a project and the resources that are allocated to it. Our work is similar to others (Holt and Laury 2002) that show how risk aversion is not fixed for an individual; rather it depends on the context in which the individual makes decisions. For Holt and Laury (2002) this context is the individual’s wealth. For our experiment the context is multidimensional, involving the interaction of rewards and penalties. We point out how rewards and penalties can be purposefully balanced or imbalanced to alter the risk appetite of the manager. This is in the same spirit as Akerlof and Kranton (2005), who highlight that including a person’s “identity” (in the sense that preferences define one’s identity), as a variable that can be altered is an important and often overlooked aspect of current studies.

While the relationship between our research and existing studies is certainly important, the real value of our results lie in the insights that allow us to better understand the managerial context in which new product development occurs. Firms have a limited number of levers they can use to influence the implementation and management of new product development activities. These levers consist of the managerial control that is granted to project managers, the explicit incentives that are offered, and the implicit penalties that evolve based on the culture of the organization or the tone that is set by the senior management. These factors do not act in isolation, yet surprisingly little has been done to explore their interactions.

Our results show that, as predicted, rewards have a positive effect on resource allocation while penalties have a negative effect on resource allocation. If project control is shared between two managers, the link between either reward or penalty

and the resource allocation decision is not as strong. The implication is that the positive effects of rewards and the negative effects of penalties are muted when control is shared in a collaborative innovation initiative. Although this intuition is echoed in models of free riding, it is worthwhile to point out that the result in our experiment is more nuanced. Free-riding seems to dominate when rewards are high or penalties are low in a shared control setting. However, when rewards are low or penalties are high, shared control drives managers to invest more than when they maintain individual control.

We also show when and how subjects may alter their risk appetite in response to the incentives that are offered and the penalty for failure that manifests itself in the culture of the firm. Our analysis of the manager's risk appetite is not aimed at advocating more (or less) risk taking; rather it provides insight into how the firm might influence risk appetite given the firm's objectives for collaborative innovation. Figure 17 depicts how a manager's risk appetite differs based on the rewards offered within either a low or high penalty organization. When rewards are balanced with organizational penalties, the manager will tend to take more risk. Alternatively imbalanced rewards and penalties elicit less risk appetite on the part of the manager. While there are multiple avenues to arrive at increased or decreased risk appetite, they are not all equal. Depending of the particular mix of rewards and penalties, managers may invest more or less, and the firm may retain a higher or lower share of profits when projects succeed.

These insights have significant short and long term implications for the firm. The penalties imposed on managers emerge from the organizational culture, which is, for all intents and purposes, fixed in the short term (Schein 2010). As such, the firm can only alter incentives (rewards) in the short term. Changing penalties requires cultural change, which is usually a long term undertaking. To increase manager's risk appetite and promote risk taking, the firm must offer rewards on par with the

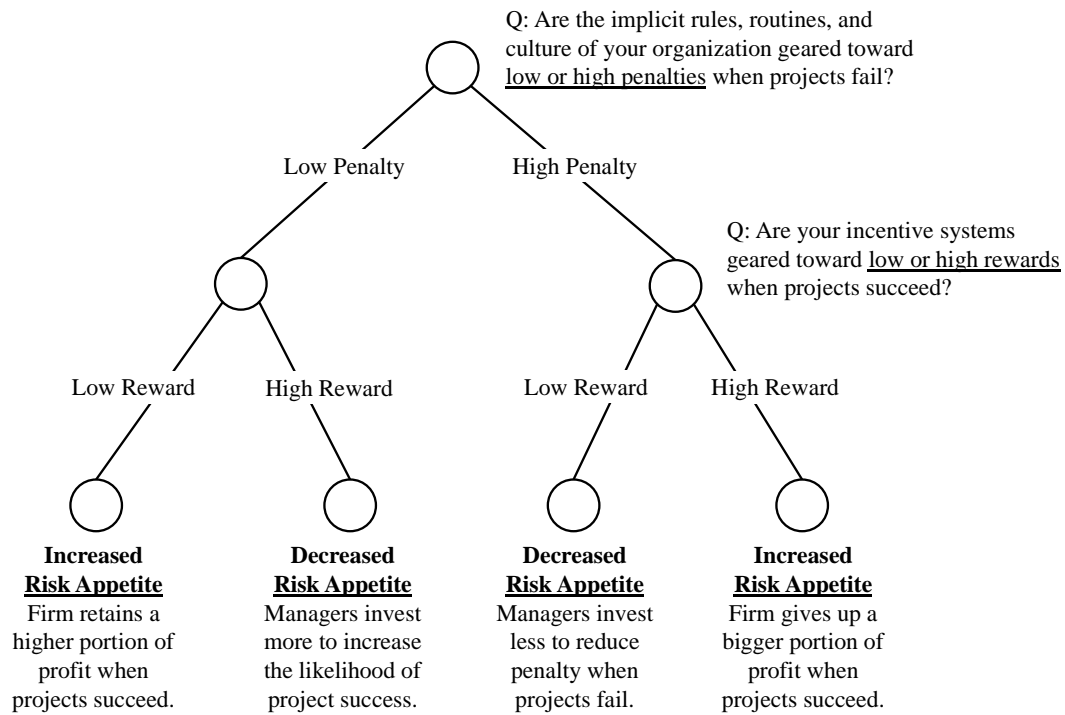


Figure 17: Implication of Balanced or Imbalanced Rewards and Penalties.

culture of penalty in which they operate. Clearly, when promoting risk taking, a low penalty environment is preferred to high penalty environment, since the latter requires that the firm forfeit a large portion of the profits in order to elicit such risk preferences. Doing so may prompt the firm to forego otherwise attractive projects, as the net benefit to the firm no longer justifies the risk. This may, in the end act as a bound on the firm's ability to expand its innovation portfolio. If this is the case it may be wise for the firm to set forth a plan to make the organizational climate within which the project managers operate more tolerant of failure.

Economic growth depends on successful innovation and new product development, and most innovation initiatives require significant collaboration between individuals. Our work is but one step toward an understanding of how incentives and tolerance for failure can be used to impact the decisions and outcomes of collaborative innovation teams.

Appendix A

For A.1 through A.3 $\rho = 0$ (in A.4. we relax this assumption). We also note that we have normalized the reservation utility of the functional specialists (following convention, we will term the functional specialists “agents” for the rest of the analysis) to zero and we make the assumption that the firm can not “sell the firm” to the agents.

A.1. Proof of Lemma 1 The expected utility of either (symmetric) agent under functional incentives is $u_{fi}[k_{fi}, c, v_i] = k_{fi}v_i - \frac{ce_i^2}{2}$, $i \in \{m, t\}$ and under project incentives is: $u_p[k_p, b, c, v_m, v_t] = k_p(v_m + v_t + bv_mv_t - v_m^2 - v_t^2 - 2\sigma^2) - \frac{ce_i^2}{2}$, $i \in \{m, t\}$. For both types of incentives the utility is concave in the decision variable of the agents (e_m or e_t). We also note that senior management’s utility under either incentive plan is concave in e . so long as $b \leq 2$. Thus we assume for all analysis that follows that this condition is met. First, we solve for the case of functional incentives. For functional incentives the equilibrium action is independent of the other agent’s actions for all b , and as such we simply solve for the FOC to get the effort that satisfies incentive rationality: $e_{fi}^* = \frac{k_{fi}}{c}$. We note that for symmetric c equilibrium effort is symmetric. We next look at project incentives. We derive the FOC to get the best response of either agent. Agent i ’s best response to the action of agent j is: $e_i = \frac{k_p(1+be_j)}{c+2k_p}$. By symmetry we arrive at the equilibrium action (that satisfies incentive rationality) under project incentives: $e_p^* = \frac{k_p}{c-(b-2)k_p}$. \square

A.2. Proof of Lemma 2 Note the utility of either agent given their choice of effort: $u_f[k_f, c, j] = \frac{k_{fi}^2}{2c} > 0, \forall k_{fi}, c > 0$ and as such the participation constraint will never be binding for functional incentives. Thus in order for the incentive rationality to be satisfied we substitute e_f^* into the firm’s profit function (and note that $k_{fm} = k_{ft} = k_f$ by symmetry and thus henceforth we drop the subscript i . Additionally, we will, for clarity, make use of the following substitutions: $\beta \triangleq b - 2$ (and note the requirement that $\beta \leq 0$), $\gamma \triangleq 1 + 2\beta\sigma^2$, and $\xi = \frac{1}{2}(2 - b\rho)\sigma^2$:

$u_{fs}[k_f, \beta, c, \sigma^2] = \frac{1}{c^2} (\beta k_f^2 + 2ck_f(1 - k_f) - 2c^2\xi)$. Note from the first and second order conditions we arrive at the condition that $b \leq 2(1 + c)$, which is satisfied by our assumption of $b \leq 2$. Thus for the remainder of our analysis we will assume interior solutions and $b \leq 2(1 + c)$. With this condition on b satisfied, the firm profits are concave and from the FOC we solve for the optimal incentive parameter $k_f^* = \frac{c}{2(1+c)-b}$. We also note for future analysis that the firm's optimal profit under functional incentives is $u_{fs}[b, c, \sigma^2]^* = \frac{1}{2(1+c)-b} - 2\xi$. Now for project incentives, by inspection of the agent's utility that satisfies incentive rationality, $u_p[k_p, \beta, c, \xi] = \frac{k_p^2(3c-2k_p\beta)}{2(c-k_p\beta)^2} - 2k_p\xi$, clearly it is possible for the participation constraint to be binding. Given such we can formulate the lagrangian for the firm's objective incorporating both the incentive rationality and participation constraint (PC):

$L[k_p, \lambda, \cdot] = (1 - 2k_p) \left(\frac{k_p(2c-k_p\beta)}{(c-k_p\beta)^2} + 2\xi \right) + \lambda \left(\frac{k_p^2(3c-2k_p\beta)}{2(c-k_p\beta)^2} - 2k_p\xi \right)$. Checking for concavity we arrive at the condition $b \leq 2 \left(1 + \frac{2c}{3-2k_p} \right)$ which we note is satisfied by our assumption of $b \leq 2$. When $\lambda \geq 0 \Rightarrow k_p = \frac{c(3+8\beta\xi-\sqrt{9+16\beta\xi})}{4\beta(1+2\beta\xi)}$. Solving for λ we obtain: $\lambda = 2 - \frac{2c^2(1-k_p)}{k_p(3c(c-\beta k_p)+\beta^2 k_p^2)-2(c-\beta k_p)^3\xi}$ and substituting k_p when the PC is active, $\lambda[\cdot] = \frac{2(\beta-2c)}{\beta-6c}$. $u_{ps}[\cdot]$ is decreasing in the variance, we solve for $\mu = 0$ and the associated variance corresponds to the point where the participation constraint is active. Thus, for $\sigma^2 \leq \bar{\sigma}^2 = \frac{(8\beta-7c)(2\beta-5c)(\rho-2)+\sqrt{(25c-8\beta)(2\beta-7c)^2c(\rho-2)^2}}{16\beta(\beta-2c)^2(\rho-2)^2}$, the PC is not binding and likewise for $\sigma^2 > \bar{\sigma}^2$ the PC is active. All we have left is to solve the unconstrained (PC not binding) case for the firm. Given our conditions for concavity, we can simply take the FOC of the firm profit function and then invoke the implicit function theorem (IFT) to solve for k_p such that k_p solves $G[k_p, \cdot] = \beta^2\gamma k_p^3 - 3\beta c\gamma k_p^2 + 2c^2(1 + \beta + \gamma)k_p - c^2(1 + 2c\xi) = 0$.

We note the following assumptions: i) the agent can not “sell the firm to the agents”, nor can there be any payments rendered by the agents to the firm; ii) any fixed wage the firm offers to the agents is not contingent on output and must be paid to the agents (no ex-post renegotiation); iii) both agents are risk neutral (along with senior

management); the efforts of both agents are non-verifiable, i.e. no contract can be written (more importantly one can not be enforced) on the explicit effort of either agent; and v) the reservation utility of the agents is zero. Thus, we claim that the firm never optimally offers a fixed wage (i.e. one that is not contingent on output) to the agents. First, consider functional incentives. Let u_{fi} and u_{fs} be the utility and firm profit when $w_f = 0$ and u'_{fi} and u'_{fs} be the specialist's and senior management's (SM) utility when $w_f > 0$. Suppose $w_f^* > 0$. Note, the agents participation constraint still never binds (yet now the agents can exert zero effort and still earn $w_f > 0$) and the optimal effort choice of the agents remains the same $\frac{k_f}{c}$ (as w_f is not a function of effort). Thus $u'_{fs} = u_{fs} - 2w_f < u_{fs}$. For project incentives we know that when the PC is not binding the same relationship as we just showed for functional incentives holds. Now if the participation constraint is binding, offering the agent $w_p > 0$ is equivalent to transforming an agent with capability c into one with capability $c - \frac{2(c-\beta k_p)^2 w_p}{k_p^2} < c$, which yields the firm strictly less profit. \square

A.3. Proof of Proposition 1 Note that u_{fs} is linearly decreasing in the σ^2 . Next we evaluate the profit when $\sigma^2 = 0$. We can equate the profit under functional incentives with $\sigma^2 = 0$ with $u_{ps}[k_p, \cdot]$ giving us another implicit equation for k_p . We solve for \hat{k}_p , the parameter that would be required in order for the profits to be equal and get $\hat{k}_p = \frac{(5\beta-8c)c}{\beta(3B-4c)}$ (excluding the trivial solution of $\hat{k}_p = 0$) and substitute \hat{k}_p into $\frac{\partial u_{ps}}{\partial k_p}$ and find that this is negative at $k_p = \hat{k}_p$ suggesting that the firm profits under project incentives are always less than functional incentives. Next, we know that the maximum project under project incentives will be such that the PC is binding. We can then find this project by equating $k_p^* = \frac{c(3+8\beta\xi-\sqrt{9+16\beta\xi})}{4\beta(1+2\beta\xi)} = 1/2$, we solve for $\sigma_{pmax}^2 = \frac{\beta-3c}{(\beta-2c)^2((2+\beta)\rho-2)}$. Solving for the maximum variance project under functional incentives, we get $\sigma_{fmax}^2 = \frac{1}{(\beta-2c)((2+\beta)\rho-2)}$ and we can note that $\sigma_{pmax}^2 > \sigma_{fmax}^2$ and since u_{fs} is linearly decreasing in σ^2 and that u_{ps} is continuous and convex in σ^2 for non-binding PC and concave in σ^2 for binding PC, there exists a crossing point

with respect to σ^2 , such that above this crossing point project incentives dominate and below functional incentives dominate. We also note that the crossing point between functional and team incentives always occurs when the PC is non-binding for team incentives. This can be shown by solving for the point at which u_{fs} crosses u_{ps} under a binding PC. Then it is straightforward to show that the variance at which point u_{fs} crosses u_{ps} under a binding PC is strictly less than the variance at which point team incentives go from a non-binding constraint to a binding one. When we do this we get the following relationship: $\frac{54\beta c - 16\beta^2 - 35c^2 + (7c - 2\beta)\sqrt{c(25c - 8\beta)}}{32\beta(\beta - 2c)^2} > \frac{(3c - \beta)(\beta - 2c)\sqrt{(2c - \beta)c + 2(2c - \beta)(\beta^2 - 3\beta c + 3c^2)}}{4(\beta - 2c)^2(\beta - c)^2}$ This combined with the concavity of the profit under team incentives shows that the crossing point between functional and team incentives strictly occurs when team incentives are non-binding. \square

Corollary 1 follows directly from σ_{pmax}^2 and σ_{fmax}^2 . \square

A.4. Proof of Proposition 2 The proof for the first claim regarding functional incentives is straightforward as the correlation does not play into the optimal $k_f^* = \frac{c}{2c - B}$.

The proof that project incentives are decreasing in the correlation follows from the IFT. We define $G'[k_p, b, c, \sigma^2, \rho] = c^2 - 4c^2 k_p + 3\beta c k_p^2 - \beta^2 k_p^3 - (c - \beta k_p)^3 \sigma^2 (b\rho - 2)$ which implicitly defines k_p^* when the PC is not binding. The claim has two possibilities corresponding to $b \geq 0 \Rightarrow \frac{\partial k_p^*}{\partial \rho} \leq 0$. We will present the argument for $b > 0$ where the case of $b < 0$ follows the same reasoning. We prove the claim by contradiction. Suppose that project incentives k_p^* were increasing in ρ when $b > 0$. Let $\rho' < \rho''$. We know by IFT that $G'[k_p^*[\rho'], \rho', \cdot] = 0$, and if k_p^* is increasing in ρ then this would imply that $G'[k_p^*[\rho'], \rho'', \cdot] > 0$ which implies that $\frac{\partial G'}{\partial \rho} > 0$, but $\frac{\partial G'}{\partial \rho} = -b\sigma^2(c - \beta k)^3$ and we know from the incentive rationality and non-negativity of effort that $(c - \beta k) > 0$. This is a contradiction. Thus, k_p^* is decreasing in ρ .

In order to show that the firm profits are increasing in ρ , we begin with team incentives. Similar to the last claim we have two cases corresponding to $b \geq 0$, and

for consistency, we will prove the case of $b > 0$ where $b < 0$ follows the same argument. Following our convention, let $\rho' < \rho''$. Then, taking advantage of symmetry, we can represent the optimal firm profits when $\rho = \rho'$ as $u_{ps}^*[k_p^*[\rho', \cdot], \rho', \cdot] = (1 - 2k_p^*[\rho', \cdot])(e^*(2 + \beta e^*) - 2\sigma^2 + b\rho'\sigma^2)$ and since the incentive rational effort of the agents is independent of ρ we know that (for $b > 0$) $u_{ps}^*[k_p^*[\rho', \cdot], \rho', \cdot] < u_{ps}^*[k_p^*[\rho', \cdot], \rho'', \cdot]$, $\forall \sigma^2 > 0$ as a result of the direct effect of ρ . Now suppose the optimal firm profits decreased in ρ . This would require that $u_{ps}^*[k_p^*[\rho'', \cdot], \rho'', \cdot] \leq u_{ps}^*[k_p^*[\rho', \cdot], \rho'', \cdot]$. The definition of optimality requires $u_{ps}^*[k_p^*[\rho'', \cdot], \rho'', \cdot] \geq u_{ps}^*[k_p^*[\rho', \cdot], \rho'', \cdot]$, the only solution to this set of inequalities is $u_{ps}^*[k_p^*[\rho'', \cdot], \rho'', \cdot] = u_{ps}^*[k_p^*[\rho', \cdot], \rho'', \cdot]$. Which is a contradiction for all positive σ^2 . The proof for functional incentives follows the same argument as we just posed for team incentives, but using the respective representation of optimal profit: $u_{fs}^*[k_f^*[\rho', \cdot], \rho', \cdot] = e^*(2 + \beta e^* - 2k_f^*[\rho', \cdot]) + \rho'\sigma^2 - 2\sigma^2 \square$

A.5. Proof of Proposition 3 We make use of Proposition 1 and show that the argument for proposition 3 follows a similar argument. First we find the minimum level of coordination that still yields non-negative utility to senior management, under either incentive plan, i.e the marginal initiative of each feasible set. We do so under zero correlation as from proposition 2, shows, it is straightforward to extend this argument with positive correlation, thus for clarity we use zero correlation. This yields \underline{b} given functional incentives equal to: $2 + 2c - \frac{1}{2\sigma^2}$, and \underline{b} given team incentives (noting that under team incentives the PC will be binding) equal to: $\frac{8(1+c)\sigma^2 - 1 - \sqrt{1+8c\sigma^2}}{4\sigma^2}$, which can easily be verified to be less than that under functional incentives. Senior management utility under functional incentives is convex in b , while the senior management utility under a binding PC is concave in b and when the PC is non-binding the utility is convex in b . Thus if there exists a crossing point, it will be unique. We know from the proof of proposition 1, that if the crossing point exists it is between the non-binding utility curve of team incentives and the utility curve of functional incentives. Now, given these properties, we fix an initiative $\hat{x} = (\hat{\sigma}^2, \hat{\rho})$, and the

characteristics of the organization for such an initiative $\hat{y} = (\hat{b}, \hat{c})$, such that it is the marginal initiative where it yields positive utility to senior management and senior management is indifferent between offering either a functional or team incentive plan. Thus for initiative \hat{x} and organization \hat{y} , $u_{ps}^* = u_{fs}^* = \hat{u}_s$. An increase in the organization's ability to coordinate, moves to the right along each curve. Since we cross from below with functional incentives, such a move would mean that the utility to senior management under functional incentives is higher. Similar, with a decrease in the coordination ability the higher utility is under team incentives. \square

Asymmetric capabilities In order to investigate the effects of the dispersion of capabilities on the firm profits and resulting choice of performance plan, we need to restate the formulation of the firm profitability. First as we are now relaxing the assumption of symmetry, we will forego the effect of correlation and complementarity. Thus we now formulate the problem with two agents, one low capability and one high capability, with the average capability (cost of effort) represented by \bar{c} and the dispersion $\delta \in [0, 1)$ such that the low capability (who has a higher cost of effort) is $\bar{c}(1 + \delta)$ and the high capability is $\bar{c}(1 - \delta)$. We also now treat project incentives as team-based incentives whereby both agents receive the same compensation for the project outcome.

A.6. Proof of Proposition 4 Under functional incentives we can directly solve for the firm's optimal profit (noting that as with symmetric capabilities the PC of the agents is never active). The firm's optimal profits are: $u_{fs,asym}[\bar{c}, \delta, \cdot] = \frac{1+\bar{c}}{2+2\bar{c}(2+\bar{c}(1-\delta^2))} - 2\sigma^2$. Then $\frac{\partial u_{fs,asym}}{\partial \delta} = \frac{\bar{c}^2(1+\bar{c})\delta}{(1+\bar{c}(2+\bar{c}(1-\delta^2)))^2} > 0$. For project incentives there are several preliminary observations to point out: the high capability agent will never have incentives that are binding at their PC; only the low capability agent will. This is straightforward if we simply look at the difference between the two agents' utility given their incentive rational effort and common incentives: $u_{pH}[\cdot] - u_{pL}[\cdot] = \frac{\bar{c}\delta k_p^2}{(\bar{c}(1+\delta)+2k_p)^2} > 0$, where the H and L subscripts on the utility refer to

high and low capability, respectively. Thus to show the second and third claims, it is sufficient to evaluate the maximum variance project for which the firm can profitably offer project incentives. We find this project by solving for $\sigma_{pmax,asym}^2$ that satisfies $\sigma^2 : u_{pL}[\sigma^2, k_p = 1/2, \cdot] = 0$ and we get that $\sigma_{pmax,asym}^2 = \frac{2-\bar{c}(3\delta-\bar{c}(1-\delta)(3+\delta)-5)}{8(1+\bar{c}(1-\delta))^2(1+\bar{c}(1+\delta))}$. Differentiating with respect to δ we find $\frac{\partial \sigma_{pmax,asym}^2}{\partial \delta} = \frac{c}{8} \left(\frac{2}{(1+\bar{c}(1-\delta))^2} - \frac{2}{(1+\bar{c}(1-\delta))^3} - \frac{1}{(1+\bar{c}(1+\delta))^2} \right)$. We find where this is increasing or decreasing and note that the common denominator $-(1-\bar{c}(1-\delta))^3(1+\bar{c}(1+\delta))^2 < 0$ allows us to equivalently evaluate when $N[\bar{c}, \delta] = 1 + \bar{c} - \bar{c}^2 - \bar{c}^3 - \bar{c}\delta - 6\bar{c}^2\delta - 5\bar{c}^3\delta + 7\bar{c}^2\delta^2 + 5\bar{c}^3\delta^2 + \bar{c}^3\delta^3 \gtrless 0$. Thus when $N[\cdot] \gtrless 0 \Rightarrow \frac{\partial \sigma_{pmax,asym}^2}{\partial \delta} \lesseqgtr 0$. Note $N[\cdot]$ is convex so we can find the minimum through the FOC, where we find it occurs at $\hat{\delta} = \frac{2\sqrt{13+22\bar{c}+10\bar{c}^2}-7-5\bar{c}}{3\bar{c}}$. Substituting $\hat{\delta}$ back into $N[\cdot]$ we find that for $\bar{c} \lesssim 0.607$, $\sigma_{pmax,asym}^2$ is decreasing in δ for all $\delta \in [0, 1)$; for $0.607 \lesssim \bar{c} < 1$ for low and high δ , $\sigma_{pmax,asym}^2$ is decreasing, and moderate δ it is increasing, and for $\bar{c} \geq 1$, $\sigma_{pmax,asym}^2$ is increasing for low enough δ and decreasing for high enough δ , where the requirement for $\sigma_{pmax,asym}^2$ to be decreasing in δ is increasing in \bar{c} . From this the last two claims follow. \square

A.7. Proof of Lemma 3 We derive the expected compensation and effort expenditure of either agent. Recall from Lemma 1, $e_b^* = \frac{k_f}{c}$. Thus we need to derive k_{fL}^* and k_{fH}^* . We first derive $u_{fs,asym}[\cdot] = \frac{1}{\bar{c}(1-\delta)} (k_{fH} - k_{fH}^2) + \frac{1}{\bar{c}(1+\delta)} (k_{fL} - k_{fL}^2) - \frac{1}{\bar{c}^2} \left(\frac{k_{fH}^2}{(1-\delta)^2} - \frac{k_{fL}^2}{(1+\delta)^2} \right) - 2\sigma^2$. It can easily be checked that $u_{fs,asym}[\cdot]$ is concave in k_{fH}, k_{fL} and as such we can use the FOC to derive $k_{fH}^* = \frac{\bar{c}(1-\delta)}{2(1+\bar{c}(1-\delta))}$ and $k_{fL}^* = \frac{\bar{c}(1+\delta)}{2(1+\bar{c}(1+\delta))}$. Then $e_{fH}^* = \frac{1}{2(1+\bar{c}(1-\delta))}$ and $e_{fL}^* = \frac{1}{2(1+\bar{c}(1+\delta))}$. Thus comparing the two we get, $e_{fH}^* > e_{fL}^*$. From the optimal effort and incentives we can derive $u_{fH} = \frac{c(1-d)}{8(1+c(1-d))^2}$, $u_{fL} = \frac{c(1+d)}{8(1+c+cd)^2}$ \square

A.8. Proof of Proposition 5 From the profit and utility derived in the prior Lemmas, we can find the maximum profitable initiatives the firm can implement under either incentive mechanism. $u_{fs,asym}[\cdot] = \frac{1+\bar{c}}{2+2\bar{c}(2+\bar{c}(1-\delta^2))} - 2\sigma^2$. It follows that $\sigma_{fmax,asym}^2 = \frac{1+\bar{c}}{4+4\bar{c}(2+\bar{c}(1-\delta^2))}$. We also can derive $\sigma_{pmax,asym}^2$ by equating $u_{pL}[k_p = \frac{1}{2}, \cdot] =$

0. We obtain the solution, $\sigma_{pmax,asym}^2 = \frac{2+\bar{c}(5-3\delta+\bar{c}(1-\delta)(3+\delta))}{8(1+\bar{c}(1-\delta))^2(1+\bar{c}(1+\delta))}$. We derive the difference as $\sigma_{pmax,asym}^2 - \sigma_{fmax,asym}^2 = \frac{\bar{c}(1-\delta)}{8(1+\bar{c}(1-\delta))^2}$. Which is decreasing for $\delta > \frac{\bar{c}-1}{\bar{c}}$ and we note the difference is zero as $\delta \rightarrow 1$. \square

Appendix B

B.1. Proof of Proposition 6 From Definition 3 the expected profit for the VP is: $\Pi = \theta P[R]V - R - W$. The VP maximizes $\max_{R,w} \theta P[R]V - R - w$ such that: $w - k_p R(1 - \theta P[R]) \geq 0$ ($\underline{U} = 0$). For the problem to be well behaved (concave utility for the VP) the second order derivative must be negative: $\left(\frac{\partial P[\cdot]}{\partial R}\right) / \left(\frac{\partial^2 P[\cdot]}{\partial R^2}\right) < -(V + k_p R)/(2k_p)$. Next, from the first order conditions we arrive at the implicit solution for the optimal resources: R^{fb} solves $\frac{\partial P[\cdot]}{\partial R}(V + k_p R) - k_p(1 - P[\theta, R]) - 1 = 0$ or equivalently, R^{fb} solves: $\frac{\partial P[R]}{\partial R}\theta(V + k_p R) - (1 + k_p(1 - \theta P[R])) = 0$. With the participation constraint binding the VP's profit becomes: $\theta P[R]V - R - k_p R(1 - \theta P[R])$ and solve for $P[\theta, R]$: $P[\theta, R] = \left((\hat{\Pi} + 1 + k_p)R\right) / (V + k_p R)$. \square

Corollaries to the first-best solution are straightforward: the size of the feasible set is reduced when either k_p or $\hat{\Pi}$ increases. Note $\partial R^{fb} / \partial \theta > 0$. The proof is as follows: Implicitly differentiating with respect to θ $\frac{\partial P[R^{fb}[\theta]]}{\partial R}\theta(V + k_p R^{fb}[\theta]) - (1 + k_p(1 - \theta P[R^{fb}[\theta]])) = 0$ yields (suppressing notation and letting $R = R^{fb}$) $\frac{\partial R}{\partial \theta} = \frac{1+k_p}{\theta^2 \left(2k_p \frac{\partial P[R]}{\partial R} + (k_p R + V) \frac{\partial^2 P[R]}{\partial R^2}\right)} \Rightarrow \frac{\partial R}{\partial \theta} > 0 \Leftrightarrow 2k_p \frac{\partial P[R]}{\partial R} + (k_p R + V) \frac{\partial^2 P[R]}{\partial R^2} < 0$, where the R.H.S. condition represents the condition for concavity. \square

B.2. Proof of Proposition 7 The VP has two options (or any combination of the two): w and k_s . The VP must meet the participation constraint of the PM. The worst case is: θ_d . When w is offered she offers $w = k_p R(1 - \theta_d P[R])$ (i.e highest expected penalty). If the VP chooses to use k_s , k_s must be set where $k_s \theta_d P[R](V - R) - k_p R(1 - \theta_d P[R]) = 0$, or $k_s = (k_p R(1 - \theta_d P[R])) / (\theta_d P[R](V - R))$. Clearly, when $\theta = \theta_d$ both forms of compensation are equivalent (i.e. for any wage there is an equivalent k_s that offers both manager and VP the same expected utility). For $\theta \neq \theta_d$, this does not hold. Specifically, for $\theta_e > \theta_d$, w and k_s remain the same ($w = k_p R(1 - \theta_d P[R])$ and $k_s = (k_p R(1 - \theta_d P[R])) / (\theta_d P[R](V - R))$). Then $\Pi[\theta_e]$ becomes:

(under fixed wage) $\theta_e P[R]V - R - k_p R(1 - \theta_d P[R])$, and under (profit-sharing) $(1 - \frac{k_p R(1 - \theta_d P[R])}{\theta_d P[R](V - R)})\theta_e P[R](V - R) - R(1 - \theta_e P[R])$. Subtracting the latter from the former we get: $\frac{Rk_p(1 - \theta_d P[R])(\theta_e P[R] - \theta_d P[R])}{\theta_d P[R]}$, which is both positive and increasing as the θ becomes greater than θ_d . Thus, it is always better to implement a fixed wage.

Recall that we normalize $\theta_e = 1$, so $\Pi = (q\theta_d + (1 - q))P[R]V - R - k_p\theta_d R(1 - \theta_d P[R])$. The concavity conditions for the objective are $\left(\frac{\partial^2 P[R]}{\partial R^2}\right) / \left(\frac{\partial P[R]}{\partial R}\right) < -\frac{2k_p\theta_d}{\mathbb{E}[\theta]V + Rk_p\theta_d}$, which is satisfied by the conditions imposed on the first-best scenario. We solve for R^* using the first order conditions: R^* solves $1 + k_p(1 - \theta_d P[R]) - \frac{\partial P[R]}{\partial R}(\mathbb{E}[\theta]V + Rk_p\theta_d) = 0$. $R^{fb} > R^*$ implies $\frac{\partial}{\partial R}\Pi^{fb}[R^*] > 0$ and $\frac{\partial}{\partial R}\Pi^{fb}[R] = -1 - k_p(1 - \mathbb{E}[\theta]P[R]) + \frac{\partial P[R]}{\partial R}\mathbb{E}[\theta](V + Rk_p)$ for $\theta = \mathbb{E}[\theta]$, thus R^* is defined by $P[R^*] = \frac{1 + k_p - \frac{\partial P[R^*]}{\partial R}(\mathbb{E}[\theta]V - R^*k_p)}{k_p\theta_d}$ such that if $R^{fb} > R^*$ then $-1 - k_p(1 - \mathbb{E}[\theta]P[R^*]) + \frac{\partial P[R^*]}{\partial R}\mathbb{E}[\theta](V + R^*k_p) > 0$. Substituting $P[R^*] = \frac{1 + k_p - \frac{\partial P[R^*]}{\partial R}(\mathbb{E}[\theta]V - R^*k_p)}{k_p\theta_d}$ and rearranging yields $\frac{-(\mathbb{E}[\theta] - \theta_d)(1 + k_p - \mathbb{E}[\theta]V P'[R])}{\theta_d} < 0$, which is true since $\mathbb{E}[\theta] - \theta_d > 0$, $\theta_d > 0$ and since $P[R] > 0 \Rightarrow P[R^*] = \frac{1 + k_p - \frac{\partial P[R^*]}{\partial R}(\mathbb{E}[\theta]V - R^*k_p)}{k_p\theta_d} > 0$ which implies that $1 + k_p - \frac{\partial P[R^*]}{\partial R}(\mathbb{E}[\theta]V - R^*k_p) > 0$. $\mathcal{F}^{td} < \mathcal{F}^{fb}$ follows directly from the fact that $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$, since for any $\mathbb{E}[\theta] : \Pi^{fb} = 0 \Rightarrow \Pi^{td} < 0$ since $R^*[\mathbb{E}[\theta]] < R^{fb}[\mathbb{E}[\theta]]$ and trivially $\Pi[R] < \Pi[R^{fb}] \forall R < R^{fb}$ \square

B.3. Proof of Proposition 8 The PM knows θ , the VP does not, and has no way to verify θ ex-post. A fixed wage implies the PM's objective is: $\max_R w - k_p R(1 - \theta P[R])$. This has a maximum at $R = 0$ since $w - k_p R(1 - \theta P[R]) < w$ for all $R > 0$ (only when $\lim_{R \rightarrow \infty} w - k_p R(1 - \theta P[R]) \rightarrow w$). In order to induce non-zero R , the VP uses profit-sharing with parameter k_s , with reservation utility at 0, and the PM's expected utility is $u = k_s \theta P[R](V - R) - k_p R(1 - \theta P[R])$. So, we arrive at $k_s^* = \frac{k_p R_d(1 - \theta_d P[R_d])}{(V - R_d)\theta_d P[R_d]}$. Concavity conditions on the PM's utility require: $\frac{\partial^2 P[R]}{\partial R^2} < \frac{2(R - V\theta P[R])\frac{\partial P[R]}{\partial R}}{R(V - R)}$. Note that the PM's resource allocation choice is influenced by the ratio of k_s/k_p as follows: the first order conditions are: $\theta k_s \left((V - R)\frac{\partial P[R]}{\partial R} - P[R] \right) = k_p \left(1 - \theta P[R] - R\theta\frac{\partial P[R]}{\partial R} \right)$, which implies that the PM's choice is based upon $\frac{k_s}{k_p} =$

$\frac{R\theta \frac{\partial P[R]}{\partial R} - (1-\theta P[R])}{\theta(P[R] + (V-R) \frac{\partial P[R]}{\partial R})}$. Substituting k_s^* into the first order conditions for a PM realizing $\theta = \theta_d$ yields: $\frac{k_p(-VP[R_d] + VP[R_d]^2\theta_d + (V-R_d)R_d \frac{\partial P[R_d]}{\partial R})}{P[R_d](V-R_d)}$, which yields the implicit solution for R_d^* that solves: $-VP[R_d] + VP[R_d]^2\theta_d + (V-R_d)R_d \frac{\partial P[R_d]}{\partial R} = 0$, or equivalently: $\frac{\partial P[R_d]}{\partial R} = \frac{VP[R_d](1-\theta_d P[R_d])}{(V-R_d)R_d}$. Likewise the utility for the PM realizing $\theta = \theta_e$ yields first order conditions (after substituting k_s^*): $\frac{k_p(P[R_e](VP[R_d]\theta_d - R_d) + R_d(V-R_e)P'[R_e] - P[R_d]\theta_d(V(1-R_e \frac{\partial P[R_e]}{\partial R}) - R_d(1-V \frac{\partial P[R_e]}{\partial R})))}{P[R_d](V-R_d)\theta_d}$, which yields the implicit solution for R_e^* :

$P[R_e](VP[R_d]\theta_d - R_d) + R_d(V-R_e)P'[R_e] - P[R_d]\theta_d(V(1-R_e \frac{\partial P[R_e]}{\partial R}) - R_d(1-V \frac{\partial P[R_e]}{\partial R})) = 0$, or equivalently: $\frac{\partial P[R_e]}{\partial R} = \frac{P[R_e](V\theta_d P[R_d] - R_d) - P[R_d](V-R_d)\theta_d}{VP[R_d]R_e\theta_d + R_d(V(1-P[R_d]\theta_d) - R_e)}$. The first best resource level satisfies $\frac{\partial P[R^{fb}]}{\partial R} = \frac{1+k_p(1-\theta P[R^{fb}])}{\theta(V+R^{fb}k_p)}$, equating this solution to that of the PM's we can clearly see that they are equal when $\theta_d = \frac{R(1+k_p)}{P[R](V+Rk_p)}$, where $R = R^{fb}[\theta_d] = R_d^*$. In fact this clearly follows from the objectives of the firm and the PM in that both objectives are aligned when $k_s = \frac{k_p}{1+k_p}$, thus when $\theta_d = \frac{R(1+k_p)}{P[R](V+Rk_p)}$ both $R_d = R^{fb}[\theta_d]$ and $R_e = R^{fb}[\theta_e]$. \square

B.4. Proof of Theorem 9 For such a setting we claim that for any organization with a tolerance for failure $k_p < \bar{k}_p$ there exists a crossing point between the profitability under a top-down process and that under a full-empowerment one. The proof follows from the equivalence between both $R^*[\theta_d] = R^{fb}[\theta_d]$ and $R^*[\theta_e] = R^{fb}[\theta_d]$ when $\theta_d = \theta_d^{**} = \frac{R^{fb}[\theta_d](1+k_p)}{P[R^{fb}[\theta_d]](V+R^{fb}[\theta_d]k_p)}$. Note, that when $\Pi^{fe} = q\Pi^{fe}[\theta_d] + (1-q)\Pi^{fe}[\theta_e]$ and $\Pi^{fb}[\theta_d^{**}] = \Pi^{fe}[\theta_d^{**}]$ then the only loss occurs as a result of the need to offer incentives $k_s^* = \frac{k_p R[\theta_d](1-\theta_d P[R[\theta_d]])}{\theta_d P[R[\theta_d]](V-R[\theta_d])}$, where the firm would rather offer a fixed wage, or equivalent $k_s' = \frac{k_p R[\theta_d](1-P[R[\theta_d]]\theta_d)}{P[R[\theta_e]](V-R[\theta_e])}$, resulting in a loss of: $R[\theta_d]k_p(1-P[R[\theta_d]]\theta_d)\left(\frac{1}{P[R[\theta_d]](V-R[\theta_d])\theta_d} - \frac{1}{P[R[\theta_e]](V-R[\theta_e])}\right)(V-R[\theta_e])$. R_d^* that solves: $\frac{\partial P[R_d]}{\partial R} = \frac{VP[R_d](1-\theta_d P[R_d])}{(V-R_d)R_d}$, and R_e^* solves: $\frac{\partial P[R_e]}{\partial R} = \frac{P[R_e](V\theta_d P[R_d] - R_d) - P[R_d](V-R_d)\theta_d}{VP[R_d]R_e\theta_d + R_d(V(1-P[R_d]\theta_d) - R_e)}$, both of which are independent of k_p . Thus, for $\theta_d = \theta_d^{**}$, $\Pi^{fe} = q\Pi^{fe}[\theta_d] + (1-q)\Pi^{fe}[\theta_e]$, then Π^{fe} becomes $q\Pi^{fb}[\theta_d] + (1-q)\left(\Pi^{fb}[\theta_e] - R[\theta_d]k_p(1-P[R[\theta_d]]\theta_d)\left(\frac{1}{P[R[\theta_d]](V-R[\theta_d])\theta_d} - \frac{1}{P[R[\theta_e]](V-R[\theta_e])}\right)(V-R[\theta_e])\right)$. Clearly as $q \rightarrow 1 \Rightarrow \Pi^{fe} \rightarrow \Pi^{fb}$, then for a given k_p define $\hat{q} : \Pi^{fe} = \Pi^{fb}$; then clearly increasing k_p renders $\Pi^{fe} < \Pi^{fb}$, and likewise for $q < \hat{q}$. Thus define $\bar{k}_p, \hat{q} : \Pi^{fe} = \Pi^{fb}$. Furthermore

we know that when $\theta_d \rightarrow \theta_e = 1 \Rightarrow \Pi^{td} \rightarrow \Pi^{fb}$ and $\Pi^{fe} < \Pi^{fb}$. Then from continuity in the profit functions, for $q > \hat{q}$, $k_p < \bar{k}_p$ and $\Pi^{fe}[\theta_d^{**}] > \Pi^{td}[\theta_d^{**}]$ there exists some θ'_d , where $\theta'_d : \Pi^{fe}[\theta'_d] = \Pi^{td}[\theta'_d]$ and $\theta_d^{**} < \theta'_d < 1$. We next look at the equivalence between the top-down and full-empowerment: $R^{fe}[\theta_d] = R^{td}[\mathbb{E}[\theta]] \Rightarrow \frac{\partial P[R^{fe}[\theta_d]]}{\partial R} = \frac{\partial P[R^{td}[\mathbb{E}[\theta]]]}{\partial R} \Rightarrow \frac{VP[R_d[\theta_d]](1-P[R_d[\theta_d]]\theta_d)}{(V-R_d[\theta_d])R_d[\theta_d]} = \frac{1+k_p-P[R_d[\theta_d]]k_p\theta_d}{V-qV+qV\theta_d+k_p\theta_d R_d[\theta_d]}$, solving for θ_d and abbreviating $R[\theta_d]$ as R_d we get:

$$\theta_d = \theta_d^{***\pm} = \frac{1}{2VP[R_d](qV+k_pR_d)} (qV^2 - (1-q)V^2P[R_d] + k_p(2V-R_d)R_d \pm \sqrt{Q}), \text{ where}$$

$$Q = V^4(q + (1-q)P[R_d])^2 - 4qV^3R_d + 2V^2(2q - (2-q - (1-q)P[R_d])k_p)R_d^2 + 4Vk_pR_d^3 + k_p^2R_d^4.$$

Note that $\theta_d^{***-} < \theta_d^{**} < \theta_d^{***+}$. And clearly for either θ_d^{***-} or θ_d^{***+} , $\Pi^{td}[\theta_d^{***\pm}] > \Pi^{fe}[\theta_d^{***\pm}]$ and furthermore for all $\theta_d < \theta_d^{***-} \Rightarrow \Pi^{td}[\theta_d] > \Pi^{fe}[\theta_d]$. \square

B.5. Proof of Proposition 10 The compensation decision is the same exact logic as for top-down resource allocation. The firm profit satisfies the Spence-Mirrlees (Laffont and Martimort 2001) condition: $\Pi_\theta = \theta P[R]V - R - w$. $\frac{\partial}{\partial \theta} \left(\frac{\partial \Pi_\theta}{\partial R} \right) / \left(\frac{\partial \Pi_\theta}{\partial w} \right) \leq 0$, which equates to $\frac{\partial}{\partial \theta} \left(1 - \theta V \frac{\partial P[R]}{\partial R} \right) = -V \frac{\partial P[R]}{\partial R} < 0$, which clearly satisfies the condition. Only local incentive compatibility needs to be checked. Due to the monotonicity of the $\frac{\partial R^*}{\partial \theta}$, i.e. $\frac{\partial R^*}{\partial \theta} > 0$. Similarly, $\frac{\partial w^*}{\partial \theta} > 0$. In order to create an incentive feasible separating contract (Laffont and Martimort, 2001, p. 90.) the following constraints must hold (by the Revelation Principle): (i)/, $w_{\theta_d}^* = k_p R_{\theta_d}^* (1 - \theta_d P[R_{\theta_d}^*])$ and (ii)/, $w_{\theta_e}^* - k_p R_{\theta_e}^* (1 - \theta_e P[R_{\theta_e}^*]) = w_{\theta_d}^* - k_p R_{\theta_d}^* (1 - \theta_e P[R_{\theta_d}^*])$. We can then represent w_{θ_d} as $w_{\theta_d} = k_p R_{\theta_d} (1 - P[R_{\theta_d}]\theta_d)$ and w_{θ_e} as $w_{\theta_e} = k_p (P[R_{\theta_d}]R_{\theta_d}(\theta_e - \theta_d) + R_{\theta_e}(1 - P[R_{\theta_e}]\theta_e))$. Then the VP's objective becomes (substituting w_{θ_d} and w_{θ_e} :

$$\max_{R_{\theta_d}, R_{\theta_e}} q (\theta_d P[R_{\theta_d}]V - R_{\theta_d} - k_p R_{\theta_d} (1 - \theta_d P[R_{\theta_d}])) + (1-q) (\theta_e P[R_{\theta_e}]V - R_{\theta_e} - k_p (P[R_{\theta_d}]R_{\theta_d}(\theta_e - \theta_d) + R_{\theta_e}(1 - P[R_{\theta_e}]\theta_e)))$$

Solving the FOC for R_{θ_e} yields the implicit solution for $R_{\theta_e}^*$ that solves

$$1 + k_p(1 - P[R_{\theta_e}]\theta_e) - (V + k_p R_{\theta_e})\theta_e P'[R_{\theta_e}] = 0 \text{ or equivalently:}$$

$$P[R_{\theta_e}] = \frac{1+k_p-(V+k_p R_{\theta_e})\theta_e P'[R_{\theta_e}]}{k_p \theta_e} \text{ which is the same solution as the first best. Similarly, the}$$

FOC for R_{θ_d} yields: $R_{\theta_d}^*$ that solves

$$q(1 - V\theta_d P'[R_{\theta_d}]) + k_p(q + ((1-q)\theta_e - \theta_d)(P[R_{\theta_d}] + R_{\theta_d}P'[R_{\theta_d}])) = 0, \text{ or equivalently}$$

$R_{\theta_d}^*$ solves

$$P[R_{\theta_d}] = \frac{q(1-V\theta_d P'[R_{\theta_d}]) + k_p(q - R_{\theta_d}(\theta_d - (1-q)\theta_e)P'[R_{\theta_d}])}{k_p(\theta_d - (1-q)\theta_e)}, \text{ where } R_{\theta_d} < R^{fb}[\theta_d].$$

The corollary follows since without any implementation cost, adding an additional lever (the ability to adapt the specific fixed wage allows any of the other contracts to be replicated with that presented above thus by optimality the optimal contract must be at least as good as any of the prior contracts presented. \square

B.5a. Proof of Theorem 11 It is straightforward to see that when the firm can adjust w_{θ_d} and w_{θ_e} as well as the resource levels, any solution to a top-down or bottom-up process can be replicated. It should be clear that if we construct the solution to the tailored incentive and compensation such that the firm earns $\Pi^{tc}[\mathbb{E}[\theta]]$, we can set

$$\bar{c} = \max \left\{ \max_{q, \theta} \Pi^{tc}[\mathbb{E}[\theta]] - \Pi^{td}[\mathbb{E}[\theta]], \max_{q, \theta} \Pi^{tc}[\mathbb{E}[\theta]] - \Pi^{td}[\mathbb{E}[\theta]] \right\}, \text{ which would render it sub-optimal for all initiatives. } \square$$

B.6. Proof of Proposition 12 Again, the compensation decision follows the exact same logic as in the top-down resource allocation. The following constraints must hold: (i) $w - k_p R_{\theta_d}(1 - \theta_d P[R_{\theta_d}]) \geq 0$ (ii) $w - k_p R_{\theta_e}(1 - \theta_e P[R_{\theta_e}]) \geq 0$ (iii) $w - k_p R_{\theta_e}(1 - \theta_e P[R_{\theta_e}]) \geq w - k_p R_{\theta_d}(1 - \theta_e P[R_{\theta_d}])$ (iv) $w - k_p R_{\theta_d}(1 - \theta_d P[R_{\theta_d}]) \geq w - k_p R_{\theta_e}(1 - \theta_d P[R_{\theta_e}])$. These reduce to: (i) $w \geq k_p R_{\theta_d}(1 - \theta_d P[R_{\theta_d}])$ (ii) $w \geq k_p R_{\theta_e}(1 - \theta_e P[R_{\theta_e}])$ (iii) $R_{\theta_e}(1 - \theta_e P[R_{\theta_e}]) \leq R_{\theta_d}(1 - \theta_e P[R_{\theta_d}])$ (iv) $R_{\theta_d}(1 - \theta_d P[R_{\theta_d}]) \leq R_{\theta_e}(1 - \theta_d P[R_{\theta_e}])$. Note that if both (iii) and (iv) are binding then the only solution is that $R_{\theta_e} = R_{\theta_d}$. Note the following properties: $R(1 - \theta P[R])$ obtains a unique maximum (\hat{R}) on \mathbb{R}^+ and is monotonically decreasing for $R > \hat{R}$ ($\frac{\partial}{\partial R} R(1 - \theta P[R]) = 1 - P[R] - R \frac{\partial P[R]}{\partial R}$ such that \hat{R} solves $\frac{\partial P[R]}{\partial R} = \frac{1 - P[R]}{R} \Rightarrow \forall R > \hat{R}$ $R(1 - \theta P[R])$ is decreasing). Now note there are three potential cases: (a) (i) and (iii) are binding and all other constraints are slack, (b) (i) is binding and all other constraints are binding, or (c) all constraints bind in which case $R_{\theta_d} = R_{\theta_e}$ and the allocations reduce to the single top-down resource allocation. (iii) binds when: $R_{\theta_d}(1 - P[R_{\theta_d}]) = R_{\theta_e}(1 - P[R_{\theta_e}])$. Define $\alpha[\theta] \doteq \frac{R_{\theta_d}}{R_{\theta_e}}$ (note that $\alpha[\theta]$ is decreasing in θ). Then, we can represent $R_{\theta_d} = \alpha[\theta] R_{\theta_e}$. It follows that: (iii) binds when $\alpha[\theta] < \hat{\alpha}$, where $\hat{\alpha}$ solves $\alpha R_{\theta_e}(1 - P[\alpha R_{\theta_e}]) = R_{\theta_e}(1 - P[R_{\theta_e}])$, and is slack for $\alpha[\theta] > \hat{\alpha}$. Thus for low θ (iii) is binding and for higher θ it is not. Next note that (iv) binds if $R_{\theta_d}(1 - \theta_d P[R_{\theta_d}]) = R_{\theta_e}(1 - \theta_d P[R_{\theta_e}])$ which occurs

for $\theta_d \geq \hat{\theta}_d = \frac{R_{\theta_e} - R_{\theta_d}}{P[R_{\theta_e}]R_{\theta_e} - P[R_{\theta_d}]R_{\theta_d}}$. Note that R such that (iii) binds is less than R such that (iv) binds (the condition amounts to: $(1 - P[R])R < (1 - \theta P[R])R$, which holds). Next we show that $\hat{\theta}_d < 1$ which implies that (iv) is binding for $\theta < 1$ and then remains binding for $\theta \in [\hat{\theta}, 1]$, which then implies that $R_{\theta_d} = R_{\theta_e}$ over this same interval, which implies that resource buckets reduce to the top-down process for this interval and this also gives us an ordering: low θ implies constrained (by (iii)) moderate θ allows for unconstrained solutions, and higher θ reduces to top-down. \square

B.7. Proof of Theorem 13 Follows directly from the proof above since $\hat{\theta} < \theta_e = 1$. Alternatively the replication between the full-empowerment and strategic buckets can be seen as follows:

Trivially any top-down process can be replicated with a strategic buckets process. Similarly, for two types any full-empowerment process can be represented by an appropriately constructed strategic buckets process. Denoting the respective resource bucket and full-empowerment allocations by $R_{b,\theta}$ and $R_{f,\theta}$, as we have seen before the contributions from the difficult task realization are the same when $R_{b,\theta_d} = R_{f,\theta_d}$ since $\Pi_{b,\theta_d} = \theta_d P[R_{b,\theta_d}]V - R_{b,\theta_d} - k_p R_{b,\theta_d}(1 - P[R_{b,\theta_d}]) = \Pi_{f,\theta_d} = (1 - \frac{R_{b,\theta_d}(1 - \theta_d P[R_{b,\theta_d}])}{(V - R_{b,\theta_d})\theta_d P[R_{b,\theta_d}]})\theta_d P[R_{b,\theta_d}](V - R_{b,\theta_d}) - R_{b,\theta_d}(1 - P[R_{b,\theta_d}])$ when $R_{b,\theta_d} = R_{f,\theta_d}$. Then we need to find R_{b,θ_e} such that $\Pi_{f,\theta_e} = (1 - \frac{R_{b,\theta_d}(1 - \theta_d P[R_{b,\theta_d}])}{(V - R_{b,\theta_d})\theta_d P[R_{b,\theta_d}]})P[R_{f,\theta_e}](V - R_{f,\theta_e}) - R_{f,\theta_e}(1 - P[R_{f,\theta_e}]) = \Pi_{f,\theta_e} = P[R_{f,\theta_e}]V - R_{f,\theta_e} - k_p R_{b,\theta_d}(1 - P[R_{b,\theta_d}]) \Rightarrow P[R_{b,\theta_e}] = \frac{R_{b,\theta_e} - R_{f,\theta_e} + k_p R_{b,\theta_d}(1 - \theta_d P[R_{b,\theta_d}]) + R_{f,\theta_e} P[R_{f,\theta_e}] + \frac{(V - R_{f,\theta_e})(\theta_d V P[R_{b,\theta_d}] - R_{b,\theta_d})P[R_{f,\theta_e}]}{\theta_d(V - R_{b,\theta_d})P[R_{b,\theta_d}]}}{V}$. \square

B.8. An example of strategic buckets with three types

If we solve for the top-down, full-empowerment and the strategic buckets solutions for the case of $k_p = 0.01$, $q = 1/2$, $\theta_d = .3$, $V = 8$, $P[R] = \frac{R^2}{1+R^2}$ we solve for: $\Pi^{td} = 2.16022$, $R^{td} = 1.82971$; $\Pi^{fe} = 2.22092$, $R^{fe}[\theta_d] = 1.02992$, $R^{fe}[\theta_m] = 1.78162$, $R^{fe}[\theta_e] = 2.25543$; $\Pi^{sb} = 2.19765$, $R_{\theta_d}^{sb} = 1.65614$, $R_{\theta_m}^{sb} = 1.65614$, $R_{\theta_e}^{fe} = 2.23012$. For the example below $k_p = 0.01$, $q = 1/2$. Here for the case of moderate difficulty, the full-empowerment RAP dominates that of the strategic buckets RAP.

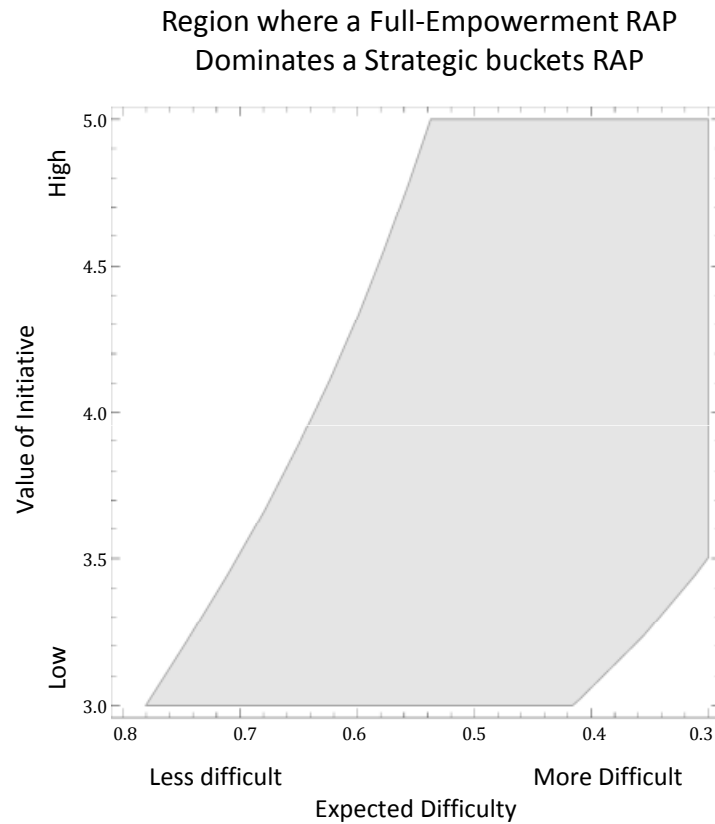


Figure 18: An example to show that when strategic buckets are defined with finer granularity than two buckets, a full-empowerment RAP may still have regions of dominance.

Appendix C

C.1. Instructions offered to subjects for both the Individual and Shared Control Groups.

Thank you for participating in our experiment.

Below we will describe the tasks that you will need to complete. Following this you will be asked to complete several questions confirming that you have read these instructions and understand the experiment.

Task description:

The company you work for has assigned you to manage 8 projects. Managing each project amounts to deciding how many resources to assign to the project.

Assigning more resources increases the likelihood that the project succeeds but it also costs the company money. In order to encourage you to assign the right number of resources, the company has offered you a reward when the project succeeds and a penalty when it fails. The reward and penalty are proportional to the number of resources you assign.

The details relating to the amount of the reward, the amount of the penalty, the probability that you receive a reward, and the probability that you incur a penalty will be provided for each number of resources that you assign (as shown below).

Number of Resources	Probability of success	Reward if successful	Probability of failure	Penalty if fails
0	0.0%	\$20	100.0%	\$0
1	28.6%	\$16	71.4%	-\$4
2	44.4%	\$12	55.6%	-\$8
3	54.5%	\$8	45.5%	-\$12
4	61.5%	\$4	38.5%	-\$16
5	66.7%	\$0	33.3%	-\$20

The next block of questions are to confirm that you understand and have read the task description. These questions will correspond to the information in the table above (the table will be shown with each question so you do not need to remember the values).

Figure 19: The introduction shown to subjects in the shared control group.

Thank you for participating in our experiment.

Below we will describe the tasks that you will need to complete. Following this you will be asked to complete several questions confirming that you have read these instructions and understand the experiment.

Task description:

The company you work for has assigned you to manage 8 projects for your division. Each of these projects receive input from your division as well as another. The project manager of the other division has the same exact information as you.

For each of the 8 projects you need to decide how many resources your division should assign to it. At the time you need to make your resource decision you cannot know how many resources the other division is assigning. The success of each of the projects depend on the total number of resources assigned, which equals the amount that you assign and the amount the other division assigns.

What you do know at the time you need to assign the resources is that the when more resources in total are assigned the likelihood that the project succeeds increases, but more resources also costs the company more money. In order to encourage both divisions to assign the right number of resources, the company has offered both you and the project manager in the other division a reward when the project succeeds and a penalty when it fails.

The reward and penalty are proportional to the number of total number of resources assigned by you and the other project manager in the other division. Both you and the other project manager receive the same penalty and same reward based on the total and not your individual allocation.

The details relating to the reward, penalty, the probability that you and the other project manager receive a reward or you incur a penalty will be provided for the TOTAL number of resources assigned to the project (as shown below).

TOTAL Number of Resources	Probability of success	Reward if successful	Probability of failure	Penalty if fails
0	0.0%	\$20	100.0%	\$0
1	28.6%	\$16	71.4%	-\$4
2	44.4%	\$12	55.6%	-\$8
3	54.5%	\$8	45.5%	-\$12
4	61.5%	\$4	38.5%	-\$16
5	66.7%	\$0	33.3%	-\$20

The next block of questions are to confirm that you understand and have read the task description. These questions will correspond to the information in the table above (the table will be shown with each question so you do not need to remember the values).

Figure 20: The introduction shown to subjects in the shared control group.

Number of Resources	Probability of success	Reward if successful	Probability of failure	Penalty if fails
0	0.0%	\$20	100.0%	\$0
1	28.6%	\$16	71.4%	-\$4
2	44.4%	\$12	55.6%	-\$8
3	54.5%	\$8	45.5%	-\$12
4	61.5%	\$4	38.5%	-\$16
5	66.7%	\$0	33.3%	-\$20

If you assign 3 resources to the project, which of the following statements is true?

- ☐ a) The project will succeed.
- ☐ b) I have a better chance of the project succeeding than failing.
- ☐ c) I earn more money by assigning more resources.
- ☐ d) I will lose \$4.

If you assign 2 resources to the project, which of the following is true:

- ☐ a) There is a 55.6% chance that the project succeeds
- ☐ b) There is a 20% chance the project succeeds
- ☐ c) The project is more likely to fail than succeed
- ☐ d) The project is more likely to succeed than fail

If you assign 2 resources to the project, you will receive the following:

- ☐ a) \$12
- ☐ b) \$-8
- ☐ c) \$4
- ☐ d) I could receive \$12 or lose \$8 depending on the outcome.
- ☐ e) Another amount not listed

How many resources would you have to assign for to receive \$16 when the project succeeds or lose \$4 if the project fails?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

Figure 21: Qualification questions given to subjects in the shared control group.

Number of TOTAL Resources Allocated	Probability of success	Reward if successful	Probability of failure	Penalty if fails
0	0.0%	\$20	100.0%	\$0
1	28.6%	\$16	71.4%	-\$4
2	44.4%	\$12	55.6%	-\$8
3	54.5%	\$8	45.5%	-\$12
4	61.5%	\$4	38.5%	-\$16
5	66.7%	\$0	33.3%	-\$20

If the total number of resources assigned is 2, which of the following is true:

-
- ☐ a) There is a 44.4% chance that the project succeeds
- ☐ b) There is a 20% chance the project succeeds
- ☐ c) The project is more likely to succeed than fail
- ☐ d) None of the answers above are true.

If you assign 2 resources to the project, which of the following are true:

-
- ☐ a) The project has a 44.4% chance of success regardless of what the other project manager does.
- ☐ b) The project has at least a 61.5% chance of success
- ☐ c) The project has no more than a 61.5% chance of success
- ☐ d) The penalty, reward and probability of success depends on the other project manager's decision.

If you knew that the other project manager assigned 1 resource, how many resources would you have to assign to have a 54.5% chance of receiving \$8?

-
- 0 1 2 3 4 5
- ☐ ☐ ☐ ☐ ☐ ☐

If you assigned 1 resource and the other project manager assigned 2 resources the following is true:

-
- ☐ a) If the project succeeds I would receive \$16 and the other project manager would receive \$12
- ☐ b) Both of us would incur a penalty of \$-12 if the project failed.
- ☐ c) The project would have a 28.6% chance of succeeding

Figure 22: Qualification questions given to subjects in the shared control group.

C.2. Calculating the Coefficient of Risk Aversion.

The procedure used to calculate the coefficient of risk aversion is similar to the one used in other studies of decision-making under risk. Recall that we used a power utility, $U(V) = V^a$, and we assumed that each subject made a utility maximizing decision. The subject's problem is to choose the resource allocation level r^* that maximizes his expected utility by solving the following problem:

$$\max_r \frac{r}{\theta + r} (\alpha(v - r))^a - \frac{\theta}{\theta + r} (\beta r)^a$$

where we have substituted the functional form for the probability of success: $p(r) = r/(\theta + r)$. Based on our assumption that the subjects act optimally, we use the observed empirical value for each subject's resource decision, \tilde{r} , and derive an estimate of the coefficient of risk aversion, \hat{a} , as follows:

$$\hat{a} = a : \tilde{r} = \arg \max_r \frac{r}{\theta + r} (\alpha(v - r))^a - \frac{\theta}{\theta + r} (\beta r)^a$$

As an example, consider the case where $\alpha = 1$, $\beta = 1$, $\theta = 15$, $v = 1000$ and $\tilde{r} = 200$. This corresponds to high reward, high penalty, low-risk project, and an observed resource decision of 10 (each unit resource presented to the subject represents an increment of 20 resources). It is straightforward to verify that a $\hat{a} = 0.377$ for this example.

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